Final Feasibility Study Area 2 of SWMU-11 Dugway Proving Ground, Dugway, Utah



Prepared for: U.S. Army Environmental Command

> Prepared by: North Wind Services, LLC

August 2020 Rev. 0

RPT-020121-002 Rev. 0

Final Feasibility Study Area 2 of SWMU-11

Dugway Proving Ground Dugway, Utah

August 2020

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Draft Final Feasibility Study Area 2 of SWMU 11, Dugway Proving Ground, Dugway, Utah W9124J-18-D-0007, Delivery Order W9124J18F0088 November 2019

1. Respondent concurs (C) or does not concur (D).

2. Commenter agrees (A) or does not agree (D) with response.

NUMBER	PAGE	SECTION	COMMENT	C, D	RESPONSE	A, D	
Reviewer #7	Reviewer #1: Christopher Grossman, Project Manager, Low-Level Waste and Projects Branch, NRC (transcribed from letter dated 1 July 2020)						
1	27-28,	7 and 9	Comment: Institutional Controls The Army should provide additional description of the legally enforceable institutional controls that would be relied upon to ensure requirements in 10 CFR20.1403(b) for sites or portions of the sites that will be released for restricted use would be met should land use controls be selected as remedial actions to meet the remedial action objectives for the option of unrestricted release. Description: Section 7 of the Army's draft feasibility study report identifies several potential general response actions being considered to meet the Army's remedial action objectives and evaluates them against specific screening criteria, including effectiveness, implementability, and cost, to determine which actions should be used in the development of the remedial alternatives. The Army identifies and evaluates that LUCs can include institutional controls and engineered controls to limit activities at the Area 2 of SWMU-11.	С	 Additional language has been added to Sections 7 and 9 to address legally enforceable institutional controls (ICs) at DPG. The following modifications were made to the text: Additional language has been added to Sections 7.2.3 and 9.2.2 to specifically address DPG as an active military installation and the authority of the Garrison Manager to enforce and regulate ICs. Enforceable restrictions will be incorporated into the Base Master Plan. Wording in Section 9.2.2 has been modified to clarify that DPG encompasses Area 2 of SWMU 11, and also trenches TR-5 and TR-6, which are currently owned and operated by the DOD. The fencing discussion of 3 to 5 strand wire has been modified to 3- strand wire. Three-strand wire will ensure predators can access the area and control burrowing animals in the soil. 		

Review Comments and Responses

NUMBER	PAGE	SECTION	COMMENT	C, D	RESPONSE	A, D	
Reviewer #7	Reviewer #1: Christopher Grossman, Project Manager, Low-Level Waste and Projects Branch, NRC (transcribed from letter dated 1 July 2020)						
			Further, the Army identifies governmental controls, enforcement tools, and informational devices as potentially feasible groups of administrative institutional controls, whereas, engineering controls include fencing to restrict physical access to Area 2. From this identification and screening evaluation, the Army identifies land use controls as a remedial action alternative in Section 8 of the draft feasibility study report for further detailed analysis in Section 9. In the description of land use controls, the Army indicates that fencing and signage would be the primary land use controls at Area 2, but does indicate, in Section 9.2.2, that Dugway Proving Ground is currently owned and operated by the DoD. NRC's criteria for restricted release of sites, specified at 10 CFR 20.1403, requires, in paragraph (b), that provisions for legally enforceable institutional controls that provide reasonable assurance that the dose from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year. The Army should ensure that the final feasibility study report describes provisions for legally enforceable institutional controls be clearly described in a future Land Use Control Implementation Plan.		 Discussion has been added to the Implementability portion of 9.2.2 to state that prior to implementation, legally enforceable ICs will be fully defined in the Remedial Design and detailed in the LUCIP. Similar updates have been made to Section 9.2.3 where applicable to LUCs. Table 8 and Appendix E have been modified to reflect these updates. 		

Review Comments and Responses

NUMBER	PAGE	SECTION	COMMENT	C, D	RESPONSE	A, D
Reviewer #7	1: Christo	pher Grossma	n, Project Manager, Low-Level Waste and Projec	ts Branc	h, NRC (transcribed from letter dated 1 July 2020))
			Basis: The NRC-DoD MOU requires that the U.S. Army's remedy at Dugway Proving Ground is consistent with the NRC's requirements in 10 CFR20.1403(b) for sites or portions of the sites that will be released for restricted use. To be consistent with NRC's criteria specified at 10 CFR20.1403(b), the Army must make provisions for legally enforceable institutional controls that provide reasonable assurance that the dose from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year.			

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APPENDICES

- Appendix A Characterization Report (included on CD)
- Appendix B Ecological Risk Screening
- Appendix C MicroShield Modeling
- Appendix D Exposure Rate Reduction Modeling
- Appendix E Cost Estimate Evaluation

ACRONYMS AND ABBREVIATIONS

$\mu R/hr$	microroentgen per hour
AEC	Army Environmental Command
ALARA	as low as reasonably achievable
ARAR	Applicable or Relevant and Appropriate Requirements
BCG	biotic concentration guidelines
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
cpm	counts per minute
СҮ	cubic yards
DCGL	Derived Concentration Guideline Level
DD	Decision Document
DoD	Department of Defense
DOE	Department of Energy
DPG	Dugway Proving Ground
DWMRC	Utah Division of Waste Management and Radiation Control
EPA	United States Environmental Protection Agency
FIDLER	Field Instrument for the Detection of Low Energy Radiation
FS	Feasibility Study
ft	feet
ft ²	square feet
GCL	Geosynthetic clay liner
GM	Geiger Mueller
GPR	ground penetrating radar
GRA	General Response Action
HDPE	high-density polyethylene
IC	Institutional Control

LTM	long-term maintenance
LUC	land use control
LUCIP	Land Use Control Implementation Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MoU	Memorandum of Understanding
mrem/yr	millirem per year
NCP	National Contingency Plan
North Wind	North Wind Services, LLC
NRC	U.S. Nuclear Regulatory Commission
O&M	Operations and Maintenance
OMB	Office of Management and Budget
pCi/g	picocuries per gram
РР	Proposed Plan
RACER®	Remedial Action Cost Engineering and Requirements
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity
RFI	RCRA Facility Investigation
RI	Remedial Investigation
SVOC	semi-volatile organic compound
SWMU	Solid Waste Management Unit
TCLP	Toxicity characteristic leaching procedure
TR	trench
U.S.	United States
UU/UE	Unrestricted Use/Unrestricted Exposure
VOC	volatile organic compound

EXECUTIVE SUMMARY

This Final Feasibility Study (FS) was prepared for Area 2 of Solid Waste Management Unit 11 (SWMU-11) at the Dugway Proving Ground (DPG) in Dugway, Utah in accordance with the Performance Work Statement for the United States Army Environmental Command (AEC) under Contract No. W9124J-18-D-0007, Delivery Order W9124J18F0088.

Area 2 of SWMU-11 at DPG is a radiological disposal area of concern located at DPG. DPG is in western Utah and covers approximately 840,000 acres in Tooele County. Records indicate Area 2 was never licensed by the U.S. Nuclear Regulatory Commission (NRC). During 2016, the Department of Defense (DoD) and the NRC finalized a memorandum of understanding (MoU) for the coordination of response actions for DoD sites containing radioactive material that are not licensed by the NRC (NRC-DoD MoU, 2016). This FS is prepared pursuant to the MoU and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986, to the extent practicable the National Contingency Plan (NCP), U.S. Environmental Protection Agency (EPA) Remedial Investigations (RI)/FS Guidance 540/G-89/004 (EPA, 1988), and is part of the overall remedial action process.

The nature and extent of contamination were initially identified in trenches TR-5 and TR-6 of Area 2 SWMU-11 in the 2005 Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) for SWMU-11 (Parsons, 2009) and the 2014 RI/FS (Cabrera, 2014) and 2016 Final Report (Cabrera, 2016). Contaminants of concern (COCs) and excavation waste volumes were calculated by Cabrera. This data was re-evaluated and defined by North Wind Services, LLC (North Wind) to determine the radiological COCs in the site Characterization Report (North Wind, 2019), which is included as **Appendix A**. The nature and extent and fate and transport are summarized in Sections 2 and 3, respectively, of this report.

Six remedial alternatives are presented in this FS and are developed, screened, and evaluated to address the site-related contaminants that were determined to pose an unacceptable risk to human health and the environment. These six remedial alternatives are:

- 1. No Action;
- 2. Land Use Controls (LUCs);
- 3. Containment through capping;
- 4. Excavation, Disposal, and Backfilling;
- 5. Excavation, Sorting, Screening, and Disposal; and
- 6. Soil Stabilization

Effectiveness, implementability, and cost are used to screen these six alternatives and to select which alternatives are carried forward in the Feasibility Study. Closure standards, including NRC standards 10 CFR 20.1402 and 10 CFR 20.1403, are addressed in this FS. Evaluation criteria, including overall protection of human health and the environment; compliance with chemical-, location-, and action-specific applicable or relevant and appropriate requirements (ARARs); long- and short-term effectiveness; reduction of toxicity, mobility, volume, and mass of contamination; implementability; and cost, were used to evaluate each remedial alternative in an individual and comparative analysis. The results of that analysis are presented herein.

1 INTRODUCTION

DPG is located in western Utah on approximately 840,000 acres in southern Tooele County (**Figure 1**). The facility is bordered to the northeast by the Cedar Mountains and to the north-northwest by Wendover Air Force Range. DPG currently serves as the Army's designated Major Range Test Facility for chemical and biological defense.

SWMU-11, also known as DPG-011 and the East Granite Holding Area, is located in the remote southwest portion of DPG and lies within a small canyon on the east side of Granite Mountain. SWMU-11 is divided into two distinct areas: Area 1 and Area 2. Area 1 of SWMU-11 consists of three closed trenches (TR-1, TR-2, and TR-3) running roughly east-west along the north side of the canyon and a fourth backfilled trench (TR-4) running north-south. Area 1 of SWMU-11 was previously evaluated and closed under RCRA and corrective action requirements of the Utah Division of Waste Management and Radiation Control (DWMRC). Area 2 (0.86 acres) of SWMU-11 is a radiological disposal area of concern and consists of two trenches (TR-5 and TR-6) and the area adjacent to the trenches. Area 2 previously contained a CONEX container; however, it was determined to be radiologically clear and was removed in 2017 (Marsh, 2017). This FS specifically addresses Area 2 of SWMU-11. **Figure 2** shows the Area 2 boundary and trench locations.

Area 2 of SWMU-11 at DPG is a radiological disposal area of concern that records indicate was never licensed by the NRC. During 2016, the DoD and the NRC finalized a MoU for the coordination of response actions for DoD sites containing radioactive material that are not licensed by the NRC (NRC-DoD MoU, 2016). This FS is prepared pursuant to the MoU and CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986, to the extent practicable the NCP, EPA RI/FS Guidance 540/G-89/004 (EPA, 1988), and is part of the overall remedial action process.

1.1 Purpose and Organization of Report

The FS report serves as the mechanism for the development, screening, and detailed evaluation of remedial action alternatives to address site-related contaminants that pose an unacceptable risk to human health or the environment. Remedial actions that reduce or eliminate the threat, while complying with ARARs and satisfying the other criteria established in CERCLA §121 (b)(1), were developed, screened, and evaluated to support risk management decisions.

This FS report is organized into 11 sections:

- Section 1 provides an introduction to the report and site background information, including the site history and previous investigations,
- Section 2 discusses nature and extent of contamination,
- Section 3 discusses contaminant fate and transport,
- Section 4 identifies the radiological COCs and the development of Derived Concentration Guideline Levels (DCGLs),
- Section 5 identifies human and ecological receptors and exposure routes,
- Section 6 identifies and discusses the RAOs, ARARs, and remedial goals.

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- Section 7 identifies and discusses the development of general response actions, and the screening of remedial alternatives.
- Section 8 provides a discussion of the development of remedial alternatives.
- Section 9 provides a detailed analysis and comparison of remedial alternatives using evaluation criteria.
- Section 10 presents a summary and conclusion of the FS.
- Section 11 presents the references cited herein.

1.2 Background Information

1.2.1 Site History

In the DPG RCRA Facility Application, SWMU-11, Area 2, was one of seven reported radioactive landfills. Historic records regarding radiological materials handling were summarized in the 2009 Phase II RFI (Parsons, 2009). Specific records regarding radiological materials disposed at SWMU-11 are limited. The East Granite Holding Area (i.e., SWMU-11) is not identified in the available literature as being associated with the testing of radiological munitions conducted at DPG in the 1950s and 1960s. Historical inspection records indicate that buried wastes in the SWMU-11 area consisted primarily of "contaminated rags and papers." Inspection records from the U.S. Atomic Energy Commission indicate that low-level radioactive waste materials were repackaged for sea disposal in the Able Area. Waste from this activity may have also been disposed at the DPG burial area corresponding to SWMU-11 after the sea disposal program was discontinued.

Radioactive waste materials from laboratory activities in other areas of DPG were stored in a CONEX container at SWMU-11 to protect individual storage containers from the elements (**Figure 2**). Materials stored in the CONEX container included Tritium and Carbon-14. In March 1980, contaminated glassware was removed from the CONEX by the DPG radiation safety officer and disposed at an off-site location. During the 2005 Phase II investigation, no waste remained in the CONEX container (Parsons, 2009). The CONEX container was determined to be radiologically clear and was removed in 2017 (Marsh, 2017).

In June 2000, DPG notified the NRC about potential radiological waste at SWMU-11. During a limited survey of the area conducted in September 2000, NRC personnel were unable to detect any radioactivity significantly above background levels. In March 2001, the NRC stipulated that any required decommissioning activities at SWMU-11 could take place under the radioactive materials license currently held by DPG. However, in March 2006, the NRC notified DPG that the NRC would evaluate if a new license was necessary to conduct decommissioning activities; no new license was issued. The current radioactive materials license was for possession of sealed sources associated with an irradiator. During 2016, the DoD and the NRC finalized a MoU for the coordination of response actions for DoD sites with radioactive materials that are not licensed by the NRC (NRC-DoD MoU, 2016). Pursuant to the MoU, the remaining investigation and remediation activities at Area 2 of SWMU-11 are being addressed under CERCLA.

1.2.1 Previous Investigations

The following is a brief description of previous investigations conducted to establish COCs which define the current nature and extent of contamination at Area 2 of SWMU-11.





Figure 1. Site Location







2005 Phase II Investigation

While investigating TR-1 through TR-4 and the surrounding area with geophysical and radiological scans during the 2005 Phase II RFI of SWMU-11 (Parsons, 2009), two additional burial trenches on the west side of TR-4 were discovered and subsequently designated as TR-5 and TR-6. The area was designated as Area 2. The following activities and samples were collected from the two trenches as part of the investigation:

- A magnetometer survey;
- A radiological survey using scanning and direct measurements;
- Four surface soil samples (0 to 0.5 feet [ft] below ground surface [bgs]) collected from TR-5;
- Two surface soil samples (0 to 0.5 ft bgs) collected from TR-6;
- One material sample collected that included metal remnants of drum material from TR-5;
- One material sample collected that included solidified sand from inside a corroded drum (approximately 2 ft bgs) from TR-6;
- One soil sample collected from the base of the test pit (10 ft bgs) to investigate potentially buried wastes in TR-6; and
- One soil boring drilled and one subsurface soil sample collected to characterize subsurface soil downgradient of Area 2.

Results of the 2005 Phase II investigation are presented on Table 1. The magnetometer survey identified anomalies in both TR-5 and TR-6; anomalous radioactivity was also measured in TR-5 and TR-6. At TR-5, surface scans identified an area of highly elevated radiological activity that was conspicuously devoid of vegetation and marked by a slight topographic depression (Parsons, 2009). Gamma exposure rate measurements ranged from 420 microroentgen per hour (μ R/hr) at the center of TR-5 to 50 μ R/hr at approximately 3 ft from center, and 30 μ R/hr at approximately 6 ft from center. Additional field measurements collected with a Field Instrument for the Detection of Low Energy Radiation (FIDLER) and a Geiger Mueller (GM) pancake probe, which measure gamma and beta radiation, respectively, produced readings between 1,200 counts per minute (cpm) and 575,000 cpm directly over the area, and readings between 75 cpm and 28,000 cpm for background levels. The soil over the anomalously elevated area was not radioactive itself but was instead covering buried radioactive waste material. Analytical results from surface and subsurface soil samples collected from TR-5 revealed a single detection of Strontium-90 (4.4 picocuries per gram [pCi/g]). The metallic remnants from drum material, collected from 0.25 ft bgs, indicated gamma spectroscopic characteristics similar to those of the surface anomaly. The metallic remnant was concluded to be a ferrous metal contaminated with Strontium-90. However, the source, depth, and quantity of material was not determined (Parsons, 2009).

At TR-6, the test pit excavation identified various types of debris, including small metal tubes from approximately 7 ft bgs that had low levels of radioactivity with signatures consistent with Cesium-137. Other types of debris, including the metal drums with solidified sand and drum cores, did not exhibit detectable levels of radioactivity. Soils underlying these materials were screened for radiation during test pit excavation and were detected at background radiation levels. However, due to the uncertainties associated with the contents of the metallic cylinders, they were not shipped for laboratory analyses. Thus, in the absence of more conclusive laboratory analysis, the waste in TR-6 was considered unidentified.

Additionally, non-radiological chemical results included detections of metals, semi-volatile organic compounds (SVOCs), and dioxins/furans at TR-5 and TR-6. In subsequent evaluations, these non-radiological chemical results were determined not to be COCs. Groundwater sampling results from SWMU-11 were also used to assess potential impacts to groundwater by site-related contamination. Groundwater samples were analyzed for volatile organic compounds (VOCs), perchlorate metals, water quality analytes, gross alpha, gross beta, gamma spectrometry, and Strontium-90; no unusual results were detected. Further investigation of the radiological portion of Area 2 at SWMU-11 was recommended in the Phase II RFI.

2014 Investigation

In 2014, Cabrera performed a non-intrusive (i.e., surface scanning) investigation at Area 2 of SWMU-11 using surficial gross gamma radiological scans and geophysical (a hand-held Schondstedt magnetometer and ground penetrating radar [GPR]) scans, as identified in the RI/FS Work Plan. The Schondstedt magnetometer and GPR investigation defined the lateral and vertical extent of TR-5 and TR-6. An area of approximately 440 square feet (ft²) (approximately 2 ft of soil cover and approximately 4 ft in depth below the covering soil) was delineated at TR-5. The radiological scans detected surface gamma emitting radioactive material at TR-5, with maximum detections in the southern half of the trench.

At TR-6, however, the GPR scan did not penetrate through the salty soil. Instead, a visual inspection detected surface debris consisting of metal tubes and possible soil piles approximately 1 to 1-½ ft high by 8 to 10 ft long. Buried metal was detected with the Schondstedt magnetometer in these low soil mounds, suggesting that debris was spread out and then covered with a thin layer of soil with an approximate surface area of 12 ft by 16 ft.

This investigation served to confirm the Phase II surface scanning results. Though elevated readings were confirmed at TR-5, there were no indications of surface elevated gross gamma activity on or around TR-6 or outside of the TR-5 boundary based on the radiological investigation (Cabrera, 2014). No laboratory samples were collected during this investigation.

2016 Investigation

In 2016, Cabrera completed the intrusive portion of the investigation (as identified in the RI/FS Work Plan) using core scanning, downhole gamma logging, and collection of samples for confirmatory laboratory analytical testing. The investigation included 15 soil boring locations (10 at TR-5 and five at TR-6), 34 soil samples, and one debris sample.

Soil cores scanned with a GM pancake probe indicated radioactive contamination in TR-5 soils exceeded the established screening criteria at two borehole locations, SB-14 (0 to 1-ft interval) and SB-15 (0 to 1-ft and 1 to 2-ft intervals), in the southern half of the trench (Cabrera, 2016). Downhole gamma logging using a sodium iodide detector confirmed that a majority of the radioactivity appeared to be within the top 3 or 4 ft of material at TR-5. However, elevated activities were identified in intervals below 4 ft bgs, and in some locations as deep as 8 ft bgs. At TR-6, only one borehole showed elevated radioactivity through downhole gamma logging; all depths within the other four boreholes showed no indication of elevated radioactivity and all readings were less than 9,000 cpm. Borehole 10, located at the northern end of the TR-6 footprint, exhibited a downhole gamma logging result of 10,504 cpm between 5 to 6-ft bgs, and radioactivity greater than 9,000 cpm within the upper 6 ft bgs of material. This borehole was located directly adjacent to a known metal anomaly; thus, the elevated readings may be attributed to this.

Laboratory analytical results detected concentrations of Bismuth-214, Lead-214, Radium-226, and Strontium-90 at TR-5 from one to two orders of magnitude greater than concentrations in other borings. While soil results did not exceed screening criteria in TR-6 (Cabrera, 2016), the six highest concentrations of Cesium-137 occurred in this trench. There were no exceedances for any chemical samples (i.e., VOCs, SVOCs, or metals) above the toxicity characteristic leaching procedure (TCLP) regulatory limits presented in 40 Code of Federal Regulations (CFR) 261.24. Therefore, it was concluded that it was unlikely that any wastes generated from the excavation of the trenches would result in hazardous or "mixed" waste.

North Wind conducted an additional review of the Phase II chemical data and noted an arsenic result of 155 milligrams per kilogram (mg/kg) from the TR-6 solidified sand from inside a drum. As a result, it was determined that TCLP analysis of the contents of drums within TR-6 may be warranted in future remedy implementation (North Wind, 2019).

2 NATURE AND EXTENT OF CONTAMINATION

Radiological COCs help to define the current nature and extent of contamination at Area 2 of SWMU-11. The maximum radionuclide concentrations at TR-6 and TR-5 were obtained from data collected by Cabrera (2016) and are presented in **Tables 2 and 3**, respectively.

2.1 TR-5 COC Extent and Characteristics

Based on the 2016 investigation, downhole gamma logging results generally support laboratory results at TR-5. Maximum concentrations of Radium-226 (3,040 pCi/g), Strontium-90 (19.2 pCi/g), Bismuth-214 (2,100 pCi/g), Niobium-94 (8.9 pCi/g), and Lead-214 (2,200 pCi/g) were reported at the 0 to 1-ft interval at SB-15. Radiological screening conducted after excavating to 1 ft bgs in three locations showed elevated gamma readings, indicating that radiological contamination was relatively homogeneous. Overall, field screening and laboratory results indicate that COCs at TR-5 are elevated within the trench, with detections exceeding background in surface and subsurface soil and the highest concentrations in the surface intervals at SB-14 and SB-15. The lateral and vertical extent of TR-5 are depicted in **Figures 3 and 4**, respectively, using downhole gamma logging data collected during the 2016 investigation by Cabrera. The inferred extent of impact (Cabrera, 2016) at TR-5 is depicted in **Figure 3**. A cross-section view of TR-5 is depicted in **Figure 4**.

2.2 TR-6 COC Extent and Characteristics

Field scanning results at TR-6 did not indicate any substantially elevated radioactivity at land surface, and laboratory soil results were uniform, with no particular sample results greatly exceeding others.

Cesium-137 was initially identified during the Phase II investigation from a debris sample taken from the small metal tubes identified at 7 ft bgs during the excavation of test pit EP-15. During the 2016 sample collection, five soil samples had Cesium-137 concentrations greater than those documented in TR-5, despite concentrations that were less than the dose compliance concentration screening levels. Downhole gamma logging identified a slightly elevated result at one location that was likely associated with a metal anomaly detected during the geophysical survey. Based on the available data, it was determined that the metallic debris in TR-6 may contain Cesium-137, particularly in the areas where geophysical anomalies were identified. The inferred lateral extent of impact at TR-6 is depicted in **Figure 3**, using downhole gamma logging data collected during the 2016 investigation (Cabrera, 2016).



From: Cabrera, 2016

Figure 3. TR-5 and TR-6 Plan View 2016 Investigation



From: Cabrera, 2016

Figure 4. TR-5 Cross Sections, 2016 Investigation

3 CONTAMINANT FATE AND TRANSPORT

3.1 Soil

Soil in Area 2 of SWMU-11 is known to contain Radium-226, Strontium-90, Bismuth-214, Niobium-94, Lead-214, and may contain Cesium-137, as described in Sections 2.1 and 2.2. Radiological constituents in soil could be transported via wind or water erosion, could be redistributed via burrowing animals, and could be assimilated into the food chain via plant uptake or direct ingestion by animals. In addition, constituents in soil could leach and migrate towards the water table as precipitation percolates through the trenches. The Characterization Report (**Appendix A**) used the Residual Radioactivity (RESRAD) ONSITE computer code (Department of Energy [DOE], 2004) to model the various potential transport and human exposure pathways for soil COCs under both a residential and an industrial land use scenario.

Debris in TR-6, identified as small metal tubes with signatures of Cesium-137, were never shipped for laboratory analysis due to the uncertainty associated with the contents. As a result, the waste in TR-6 is considered unidentified. Despite these "sealed" radioactive sources, the possibility of a leak due to aging, an accident, damage, or poor manufacture, could cause releases or migration of radioactive contamination in TR-6.

3.2 Groundwater

Groundwater in the area of SWMU-11 is part of the Dugway Valley aquifer system and is generally characterized by high total dissolved solids and flat hydraulic gradients. The flanks of Granite Mountain (including the SWMU-11 site) constitute a local recharge zone for basin groundwater in which groundwater is deeper and of higher quality than groundwater beneath the basin floor. As groundwater flows from the local recharge area toward the basin floor, it becomes increasingly laden with dissolved mineral constituents, and the quality of groundwater is greatly diminished. Thus, due to the overall low quality of groundwater in the western DPG region, there have been no potable water resources developed in the Granite Mountain area. Localized water wells provide water only for dust suppression, hand washing, and toilet flushing purposes at the U.S. Air Force Strategic Training Range Complex. Groundwater quality at SWMU-11 is Class II (drinking water quality) per Utah Administrative Code R317-6-3 (DWQ, 2019), based on the laboratory total dissolved solids measurement of 1,770 milligrams per liter (mg/L) from the groundwater sample collected by Parsons (2009).

The groundwater pathway was evaluated for Area 2 of SWMU-11 using a Resident Farmer scenario. Conservative parameter values were used for the groundwater pathway, basing the parameter values for the unsaturated and saturated zones on the typical properties of sand. Results of the Residual Radioactivity (RESRAD) ONSITE computer code (DOE, 2004) show that the travel time of radionuclides to the aquifer for all radiological COCs of interest are greater than the 1,000-year model period. Therefore, radiological COCs will not migrate to the groundwater during the assessment period. Evidence from the attempt by Parsons to install a groundwater monitoring well near SWMU-11, Area 2, indicates that the development of a water well in this area of the site may not be possible. Therefore, the groundwater pathway is not a significant contributor to the receptor doses at SWMU-11, Area 2, and is not included in this FS.

4 DERIVED CONCENTRATION GUIDELINES AND RADIOLOGICAL CONTAMINANTS OF CONCERN

DCGLs were developed for soil, consistent with 10 CFR Part 20, Subpart E, as referenced in the 2016 MoU (NRC-DoD MoU, 2016). Site-specific DCGLs were calculated for TR-5 and TR-6 using the RESRAD ONSITE computer code (DOE, 2004). A more complete discussion of this development can be found in the Characterization Report (**Appendix A**).

The DCGLs were used to define radiological COCs for Area 2 of SWMU-11, as described in the Characterization Report. The radiological COCs were then used to select a group of radionuclides and radionuclide decay chains that were modeled for the DCGLs for both TR-5 and TR-6. The following constituents were included as radiological COCs:

- C-14;
- Cs-137 + D (i.e., Ba-137m);
- Nb-94;
- Pb-210 + D (i.e., Bi-210, Po-210);
- Pu-242 + D (i.e. U-238 decay series);
- Ra-226 + D (i.e., Rn-222, Po-218, Pb-534 214, Bi-214, Po-214, Pb-210, Bi-210 and Po-210);
- Sr-90 + D (i.e., Y-90);
- Th-229 + D (i.e., Ra-225, Ac-225, Fr-221, At-217, Bi-213, Tl-209, Pb-209 and Po-213);
- Th-230 + D (i.e., Ra-226 decay series);
- Th-232 + D (i.e., Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 and Po-212);
- U-232 + D (i.e., Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 and Po-212);
- U-234 + D (i.e., Th-230 decay series);
- U-235 + D (i.e., Th-231, Pa-231, Ac-227, Fr-223, Ra-223, Rn-219, Po-215, Pb-211, Bi-211, Tl-207; Po-211 and Th-227); and
- U-238 + D (i.e., Th-234, Pa-234m, Pa-234 and U-234 decay series).

Two dose scenarios were developed using the DCGLs: (1) residential (i.e., unrestricted), which requires no LUCs or long-term maintenance (LTM) based on 25 millirem per year (mrem/yr); and (2) industrial (i.e., restricted release), which occurs after loss of LUCs or LTM based on 100 mrem/yr. The RESRAD ONSITE computer model (Kamboj et al., 2018) was used for all modeling for the development of the DCGLs. The Resident Farmer was selected as the critical group for DCGL development for unrestricted release under 10 CFR 20.1402. A Resident Farmer critical group results in more conservative DCGLs (i.e., lower concentrations) than an industrial use critical group due primarily to the increased dose from

the consumption of food grown on-site and occupancy time considerations. An Industrial Worker was selected as the critical group for DCGL development for restricted release under 10 CFR 20.1403. The Industrial Worker is considered representative of the likely future use of the Dugway site.

Soil

The Resident Farmer and Industrial Worker scenarios assume that the entire volume of contaminated soil in a trench is exhumed and spread over the ground surface, resulting in a 6-inch contaminated soil layer. This is a conservative assumption and provides a conservative estimate of the radionuclide DCGLs. Both TR-5 and TR-6 were classified consistent with guidance in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) as Class 1 Areas, meaning both have a potential for radioactive contamination based on site operating history, or known contamination based on previous radiological surveys. The buffer areas surrounding TR-5 and TR-6 were classified as Class 3 Areas, based on the radiological survey area and geophysical results indicating no surface radioactive material on or around TR-6 or outside of the TR-5 boundary.

5 HUMAN AND ECOLOGICAL RECEPTORS AND EXPOSURE ROUTES

Radiological COCs in soil and debris pose the highest potential exposure for human and ecological receptors. As the groundwater pathway was previously determined to be an insignificant contributor to the receptor doses at Area 2 of SWMU-11, it does not pose a concern for potential exposure to human or ecological receptors.

Receptors with the highest potential to be exposed to radiological soil and debris COCs include site industrial workers and ecological receptors. Area 2 of SWMU-11 does not currently house any administrative buildings, family housing, industrial facilities, or barracks, and no future construction projects or residential housing are planned for this area. Access to the site is restricted; therefore, trespassers are not expected at the site under current conditions.

Based on information from DPG staff, current usage by a site industrial worker is estimated to be approximately 2 hours per day, 5 to 10 days per year. When present, industrial workers could potentially contact impacted soil and debris. The industrial worker is considered representative of the likely future use at DPG and future land uses are anticipated to be consistent with the current land uses. Future potential contact with impacted soil and debris could include site inspections and maintenance activities. Though not identified as a current or immediate future receptor, the Resident Farmer or residential user may potentially encounter radiological COCs in the distant future.

Ecological receptors may also encounter radiological COCs in soil at TR-5 and TR-6. Current and future use by ecological receptors is expected to remain unchanged. Radiation exposure of terrestrial plants and animals was evaluated using the RESRAD-BIOTA computer model, a tool for implementing the DOE "Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE, 2002). Based on the results of the RESRAD-BIOTA output, the only exceedance of the terrestrial animal biotic concentration guidelines (BCGs) was for the maximum soil concentrations of Ra-226 at TR-5 (3,040 pCi/g). However, it is highly unlikely that any population of animals would only be exposed to the maximum soil concentration. Therefore, the average soil concentration (136.6 pCi/g) is considered a better metric of the soil concentration to which the terrestrial animals would be exposed. Based on the average soil concentrations at TR-5 and TR-6, the BCGs would not be exceeded. Further evaluation and results of the ecological risk screening are presented in **Appendix B**. This evaluation confirmed that there are no ecological COCs and therefore, remedial actions are not required to address ecological exposure pathways.

Thus, humans are identified as the primary receptors at Area 2 of SWMU-11. The identified or potential exposure routes for human receptors for the site include:

- Direct radiation,
- Inhalation of re-suspended dust, and
- Direct ingestion of soil.

6 REMEDIAL ACTION OBJECTIVES, REQUIREMENTS, AND REMEDIAL GOALS

The following sections discuss the development of RAOs, ARARs, and DCGLs as remedial goals.

6.1 Remedial Action Objectives

RAOs are site-specific, initial clean-up objectives that are established based on the nature and extent of contamination, the resources that are currently and potentially threatened, and the potential for human and ecological exposure. The purpose of the RAOs is to reduce the potential for radiological exposure, thereby limiting the dose to receptors.

The following RAOs were developed for the remediation of radiological soil and debris at Area 2 of SWMU-11:

- 1. Prevent direct contact to or external exposure from contaminated soil and radiological debris (i.e., metal tubes) by human receptors with consideration to current land uses and potential future land uses. Current and potential future receptors are identified as site industrial workers, resident farmers, and residential users.
- 2. Reduce the potential for migration of soil COCs to areas beyond the trenches (i.e., buffer zones surrounding the trenches, air, and groundwater).

6.2 Applicable or Relevant and Appropriate Requirements

This section describes the regulatory standards and guidance that may be applied to the remedial actions in accordance with 40 CFR 300.400(g). These regulatory standards and guidance requirements are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific.

6.2.1 Chemical-Specific

Chemical-specific requirements establish health-based concentration limits, risk-based concentration limits, or ranges for specific hazardous substances in different environmental media. These standards provide media cleanup levels or a basis for calculating cleanup levels for COCs. Chemical-specific standards are also used to indicate an acceptable level of discharge to determine treatment and disposal requirements for a particular remedial activity, and to assess the effectiveness of a response action. The potential chemical-specific ARARs identified for remedial action at the site include Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402) and Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403). The COCs at Area 2 of SWMU-11 are radiological COCs. Arsenic was not identified as a COC and is not driving the remedial alternatives development. The ARARs for waste characterization are adequate and appropriate to address the uncertainty regarding the single elevated detection of arsenic. Specifically, prior to off-site disposal, any excavated material would be subjected to TCLP analysis to confirm it meets the landfill criteria for acceptance.

Additional chemical-specific ARARs may include:

- 40 CFR 262.11(a), (b), (c), (d) to address the characterization of solid waste;
- 40 CFR 264.1(j)(2) to address the characterization of remediation waste;

- 40 CFR 268.7(a), 9(a) to address the determination for management of hazardous waste;
- 40 CFR 268.34(f), 49(b), (c)(1) to address land disposal restrictions; and
- 10 CFR 61.55 to address low-level waste classification and characterization.

6.2.2 Location-Specific

Location-specific requirements set restrictions on the types of remedial activities that can be performed based on specific site characteristics or location. Location-specific standards provide a basis for assessing restrictions during the formulation and evaluation of site-specific remedies. Remedial actions may be restricted or precluded based on citing laws for hazardous waste facilities and based on proximity to wetlands, floodplains, or man-made features such as landfills, disposal areas, and/or local historic buildings.

The potential location-specific ARARs identified for remedial action at the site include:

- Archaeological and Historic Preservation Act (16 USC 469; PL 93-291; 88 Stat. 174);
- Migratory Birds Act (16 USC 703); and
- Bald and Golden Eagle Protection Act (16 USC 668-668d).

Archaeological and historical resources, as well as biological activities such as nesting and breeding, are not anticipated within Area 2 of SWMU 11 due to the area having been previously disturbed. However, no surveys have been performed to rule out the presence of cultural or biological resources. If evidence of either is found during remedial work on site, work will immediately be stopped, and a cultural or biological resources specialist will be consulted. Additionally, biological activity is seasonal, so the ARAR may be season-dependent and based upon the field schedule. All remedial actions performed at TR-5 and TR-6 must consider these restrictions and meet all necessary requirements.

6.2.3 Action-Specific

Action-specific requirements set controls or restrictions on the design, implementation, and performance of actions. These standards specify performance levels, actions, or technologies and specific levels for discharge of residual chemicals. They also provide a basis for assessing the feasibility and effectiveness of the remedial alternatives.

The potential action-specific standards identified for remedial action at the site include the transportation of hazardous waste to a disposal facility (State Law, Title 19, Chapter 6, Solid and Hazardous Waste Act). All soil and debris must be transported from the site in accordance with this state law and meet all federal requirements.

Additional action-specific ARARs may include:

- 10 CFR 20.2006 and Appendix G to 10 CFR Part 20 to address the transfer for disposal and manifest of low-level radioactive waste by the generator;
- 40 CFR 262.11(a), (b), (c), (d) to address the characterization of solid waste;
- 40 CFR 262.254, 40 CFR 262.261, and 40 CFR 262.264 to address temporary on-site storage of hazardous waste and emergency procedures;
- 40 CFR 264.1(j)(2) to address characterization of remediation wastes;
- 40 CFR 264.554 (d)(1), (h), (j)(1), (k) to address operation of staging piles;
- 40 CFR 268.7(a), 9(a) to address the determination for management of hazardous waste; and
- 40 CFR 268.34(f), 49(b), (c)(1) to address land disposal restrictions.

6.3 Development of Derived Concentration Guideline Levels as Remedial Goals

As described in Section 4, site-specific DCGLs were developed for soil in TR-5 and TR-6. The Characterization Report (**Appendix A**) identified radiological COCs in soil and debris as a potential risk to human receptors, primarily site industrial workers. No risks to site workers were identified in groundwater. The remedial alternatives established for this site address the anticipated land use, RAOs, ARARs, and DCGLs as remedial goals for the site.

6.3.1 Chemical-Specific ARAR Applicability

The ARARs listed below are presented in relation to their applicability to DCGLs for site soil and debris. The COCs at Area 2 of SWMU-11 are radiological COCs.

Radiological Criteria for Unrestricted Use

ARARs for radiological COCs in soil at the site are identified in Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402). Provisions of 10 CFR 20.1402 require that the annual dose to an average member of the critical group (i.e., residential receptor) not exceed 25 mrem/yr, and that the residual radioactivity be reduced to levels that are as low as reasonably achievable (ALARA). The soil DCGLs for the residential receptor provided in **Table 4** are based on 25 mrem/yr. DCGLs are based on a dose standard (i.e., 10 CFR 20.1402 and 1403) and are used as cleanup criteria (i.e., allowable soil concentrations) for the site. Full development of the DCGLs can be found in the Characterization Report (**Appendix A**). Soil DCGLs for residential (unrestricted) use are most applicable to the remedial alternative of excavation.

Criteria for License Termination Under Restricted Conditions

ARARs for radiological COCs in soil at the site are identified in Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403). Provisions of 10 CFR 20.1403 require that the annual dose to an average member of the critical group (i.e., industrial worker receptor) not exceed 25 mrem/yr, and that the residual radioactivity be reduced to levels that are ALARA. However, 10 CFR 20.1403 allows this dose limit to be achieved through the use of engineering and LUCs, with the added requirement that the annual dose does not exceed 100 mrem/yr should those institutional controls fail or if they are no longer in effect. The soil DCGLs for the industrial receptor provided in **Table 5** are based on 100 mrem/yr. DCGLs are based on a dose standard (i.e., 10 CFR 20.1402 and 1403) and are used as cleanup criteria (i.e., allowable soil concentrations) for the site. Full development of the DCGLs can be found in the Characterization Report (**Appendix A**). Soil DCGLs for industrial (restricted) use are most applicable to the remedial alternative of LUCs and capping.

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7 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

7.1 General Response Actions

This section presents the identification and screening of potentially applicable remedial technologies for attaining the RAOs at DPG. General Response Actions (GRAs) are broad categories of remedial actions intended to satisfy the RAOs. Appropriate GRAs are developed based on the RAOs, site-specific conditions, and contaminant characteristics. They may be implemented alone or in combination to achieve cleanup criteria (i.e., DCGLs). The EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988) was the primary resource document used to select GRAs.

The following GRAs, as listed in column 1 of **Table 6**, have been identified to address radiological soil and debris contamination at DPG:

- No Action,
- LUCs,
- Containment,
- Excavation and Disposal, and
- Treatment.

7.2 Identification and Screening of Remedial Technologies and Process Options

This section describes the screening and evaluation of remedial technologies and process options, which are conducted as follows:

- Identification of remedial technologies and process options;
- Screening criteria of remedial technologies and process options;
- Evaluation of remedial technologies and process options based on effectiveness, implementability, and cost; and
- Selection of remedial technologies and process options.

7.2.1 Identification of Technologies

Remedial technologies are the general categories of technologies by which a GRA is undertaken. Process options are the specific processes within a remedial technology by which the technology may be implemented. Potential remedial technologies and process options are presented in columns 2 and 3 of **Table 6**.

7.2.2 Screening Criteria

Potential remedial technologies and process options are identified and evaluated based on technical feasibility. The retained process options are screened based on effectiveness, implementability, and cost to determine which process options should be used in the development of the remedial alternatives.

Effectiveness

The effectiveness criterion addresses the ability of a technology to meet the RAOs, including overall protection of human health and the environment; compliance with regulations; long-term effectiveness and permanence; short-term effectiveness; and reduction of toxicity, mobility, or volume by treatment. The protection of human health and the environment considers the reduction, control, or elimination of risks at the site through the use of treatment, engineering, or LUCs. Compliance with regulations considers the ability of a technology to meet regulatory requirements. Long-term effectiveness and permanence include the consideration of the magnitude of risk associated with residuals or untreated waste at the site and the adequacy and reliability of post-closure activities required to maintain the integrity of the response action. Short-term effectiveness includes the consideration of community protection from air quality impacts, fugitive dust, transportation of hazardous materials, worker protection. Reduction of toxicity, mobility, or volume includes the consideration of EPA's policy of preference for treatment and the extent and irreversibility of treatment.

Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing a technology and the availability of the materials and services required for implementation. In addition, the acceptance of a technology by regulatory agencies and the community is an important component in considering the implementability of any technology. Technical feasibility includes the consideration of the reliability, maturity, prior application, and operational difficulties, as well as logistical, climate, and terrain limitations. Administrative feasibility includes the consideration of coordinating activities with regulatory agencies and obtaining permits, easements, right-of-way agreements, and zoning variances. The availability of materials and services includes considering the availability and distance to offsite treatment, storage, and disposal facilities, and required utility connections.

Cost

The cost criterion addresses the relative magnitude of capital and operation and maintenance (O&M) costs. Capital costs consist of direct and indirect costs. Direct costs include costs associated with construction, equipment, materials, transportation, disposal, analytical services, treatment, and operation. Indirect costs include expenses related to engineering, design, legal fees, permits, and start-up. O&M costs include costs associated with operation, maintenance, energy, residual disposal, monitoring, and support.

7.2.3 Evaluation of GRAs, Remedial Technologies, and Process Options

Table 6 lists the GRAs that were evaluated based on effectiveness, implementability, and relative costs. GRAs and remedial technologies retained for further consideration and development of process options are identified. Those GRAs that do not meet the criteria for effectiveness and implementability, or that are prohibitively expensive, are eliminated from further consideration.

No Action

The No Action GRA is evaluated and retained to establish a baseline for the comparison of the GRAs and subsequent remedial technologies. No response action of any kind would be employed at the site under this category. Inclusion of No Action is required per 40 CFR Section 300.430(e)(6) and the NCP. No Action, by definition, involves no remedial action at the site and, therefore, has no technological barriers and no associated costs. The No Action GRA is not effective, as the potential risks to human health and the environment would not be mitigated nor does it reduce the toxicity, mobility, or volume of contamination through treatment.

LUCs

LUCs are a GRA consisting of institutional controls (ICs) and engineering controls used as remedial technologies to regulate activities at the site. ICs and engineering controls serve to reduce the potential for exposure to contamination; however, they do not reduce the environmental impacts. Radiological contamination present in the trenches is not physically altered nor is the mobility, toxicity, or volume of soils and debris reduced.

The use of LUCs shall not be a substitute for active response measures (e.g., treatment and/or containment of source material) as the sole remedy unless such active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of the remedy (40 CFR 300.430 (a)(iii)(D)). The objective for implementing LUCs at a site following remedy implementation is to protect remedies that are in place so that protection of human health and the environment is maintained. Additionally, LUCs serve to restrict land use until site conditions allow for unrestricted use and unlimited exposure. The EPA requires LUCs when site contaminant levels do not allow for unrestricted use and unlimited exposure.

There are significant differences in the way LUCs are applied at federal facilities as compared to other sites. Some proprietary or governmental controls cannot be applied on active federal facilities. However, for properties being transferred as part of a base closure, the DoD has authority to restrict property by retaining a property interest (i.e., an easement intended to assure the protectiveness of the remedy). For active bases, LUCs are commonly addressed through remedy selection documents, base master plans, and separate MoUs.

Based on the EPA's fact sheet, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (EPA, 2000), there are four general categories, or process options, of ICs:

- Governmental controls;
- Proprietary controls;
- Enforcement tools with institutional control components; and
- Informational devices.

At DPG, proprietary controls are not retained for consideration, as DPG is a federal facility and private property is not a current land use. Governmental controls, enforcement tools, and informational devices are collectively considered administrative controls, and are retained due to their applicability at DPG. These process options allow the facility to specify the site or land usage, limit certain activities, and do not involve third parties to establish and enforce. At an active military installation such as DPG, the Garrison Manager is the local authority for regulating and enforcing ICs and administrative controls. Administrative controls may include LUCs and restrictions, signage, and permits. Administrative controls may be addressed in the Base Master Plan and are considered easy to implement, cost-effective, and maintain relative effectiveness when considered in conjunction with other remedial technologies.

Engineering controls include the process option of fencing. This option will serve to reduce the potential for exposure to radiological soil and debris by physically limiting site access to Area 2 of SWMU-11; however, it does not reduce the environmental impact. Engineering controls are easily implementable and are considered relatively cost-effective. Fencing requires labor, materials, and logistical planning. Fencing may be installed around each individual trench or around both trenches contained together. This engineering control is retained and considered in conjunction with other technologies.

Containment

Containment of radiological COCs through the remedial technology of capping effectively minimizes surface water infiltration, controls erosion and surface water runoff, limits the potential leaching of contaminants to groundwater, and prevents direct contact to or external exposure from contaminated soil and radiological debris by human and ecological receptors. A cap will also serve to limit and/or reduce the external dose pathway, in addition to limiting erosion or dust generation of radiation-impacted soils. The cap does not pose significant impacts to human health or the environment due to construction or during the operational period. Capping is easily implementable, though capping material would require routine maintenance and inspection by a work crew. This remedial technology can be implemented with moderate capital costs and is therefore retained in conjunction with other remedial technologies.

Capping with a clay liner or a geosynthetic clay liner (GCL) are two process options evaluated for addressing radiological soil contamination within the trenches. Though both options prevent direct contact between potential receptors and impacted soil and meet RAOs, geomembranes and GCLs are often favored over traditional clay liners as they provide a higher degree of impermeability, are less susceptible to leaks, and may require less maintenance and repair over time. Though a traditional clay liner may present an up-front lower cost when compared to a GCL, a clay liner requires additional maintenance and testing over time. Proper moisture content and compaction standards must be achieved and QA/QC testing, including standard field tests with a nuclear density gauge, in-situ hydraulic conductivity tests, and laboratory tests on representative samples are typically required. In a semi-arid to arid environment, such as that at DPG, desiccation cracking is also a concern. By comparison, a GCL does not require the same level of installation effort, requires less maintenance, testing, and inspection over time, and is not subject to desiccation cracking.

Excavation and Disposal

Soil excavation of both trenches (TR-5 and TR-6) physically removes the contaminated soil and debris and disposes of radiologically impacted materials by transporting them to an approved off-site facility. Excavation is considered effective as the potential for direct exposure to or external exposure from contaminated soil and radiological debris is eliminated, as is the transport of radionuclides to surrounding soil and groundwater. Process options include confirmation soil sampling, a magnetometer survey or realtime radiation detector, and sorting and screening of radiologically impacted materials. Confirmation soil sampling would be performed following excavation to confirm removal of all radiological material. Sorting and screening of the excavated material on-site would segregate the radiologically contaminated debris (i.e., metal tubes) from the soil. A magnetometer or real-time radiation detector such as a FIDLER or a GM probe would be used to verify removal of trench-related debris and confirm soil contamination below screening levels is achieved. This would eliminate or reduce the possibility of a remobilization or re-excavation effort.

Following excavation, two options for soil replacement in the trenches are considered. One option would completely remove all soil and debris from the trenches and replace with clean backfill from a location on DPG. The other option would sort and screen all soil and debris, and return all non-radiologically impacted soil to the trench. Additional clean backfill would be added if necessary.

Generally, excavation and disposal are easy to implement and have been used at similar sites. Costs may be moderate to high and must comply with both Federal and State of Utah transportation regulations. Consideration is given to the distance required for transporting materials offsite, as well as the cost to deploy on-site sorting and screening equipment. Additional consideration is given to the location of clean backfill material and its proximity to SWMU-11. Disposal requirements are expected to be the same for materials from either trench.

Treatment

Treatment of radiological COCs through the remedial technology of in-situ soil treatment uses the process option of cementitious solidification and stabilization of soils to eliminate the potential for leaching and migration of radionuclides from the site. Soil stabilization through the use of cement grout such as Portland cement or acrylamide grout, would treat low-level radiological waste in-situ. Grout is injected under pressure across the target area (i.e., trenches). Once solidified, the mobility of radionuclides in soil has been reduced. Soil stabilization using grout injection has been used at numerous sites to treat radiological waste and has been shown to reduce water infiltration and reduce exposure rate. Operations should be generally easy to implement with moderate costs.

7.2.4 Selection of Remedial Technologies and Process Options

The evaluation of the GRAs, remedial technologies, and process options are presented in **Table 6**. The screening and evaluation resulted in retention of remedial technologies and process options to be carried forward in the feasibility study process. The retained process options are used in the development and detailed screening of the remedial alternatives. The rejected process options were eliminated from further consideration.

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8 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The primary purpose of this FS is to develop appropriate remedial alternatives to address site-related contaminants that have been determined to pose an unacceptable risk to human health and the environment per 40 CFR 300.430(e)(9). The remedial alternatives have been developed from technologies retained in the screening process, as summarized in Section 7. This section includes descriptions of the alternatives that have been retained and developed for TR-5 and TR-6 in Area 2 of SWMU-11. Although the site is not intended for residential use, remediation to unlimited use/unrestricted exposure (UU/UE) is the ideal remedial goal.

8.1 Development of Remedial Alternatives for Radiological Contaminants of Concern in Soil

The following remedial alternatives for radiological COCs in soil were developed for TR-5 and TR-6 in Area 2 of SWMU-11 with respect to site usage:

- Alternative 1: No Action;
- Alternative 2: LUCs;
- Alternative 3: Capping;
- Alternative 4: Excavation, Disposal, and Backfilling;
- Alternative 5: Excavation, Sorting, Screening, and Disposal; and
- Alternative 6: Soil Stabilization.

8.1.1 Alternative 1: No Action

Alternative 1 is the No Action alternative, as required per 40 CFR 300.430(e)(6) and the NCP. Under Alternative 1, no corrective action would be implemented. This alternative would not control the radiological hazards or risks posed by the COCs in soil and debris at either TR-5 or TR-6. This alternative would have no capital or O&M costs. Although the No Action alternative is not considered a viable remedial option, it will be evaluated to establish a baseline of comparison regarding future performance and risk for the remaining remedial alternatives.

8.1.2 Alternative 2: Land Use Controls

LUCs would be implemented to ensure protection of human health and the environment, and to ensure that land use is restricted until contaminant concentrations are at levels that allow UU/UE. The EPA requires LUCs when site levels do not achieve UU/UE. They also serve to notify current and future users about the environmental conditions of the property. Fencing and signage would be the primary LUCs employed at Area 2 of SWMU-11.

8.1.3 Alternative 3: Capping

A containment or capping technology is used for impacted trench soil. This barrier layer would eliminate potential direct contact to or exposure from radiologically-impacted soil. The cap does not pose significant impacts to human health or the environment due to construction or during the operational

period. Installation of this type of cover is a proven and effective method of providing an exposure barrier and erosion control. Currently, there are no structures or barriers at Area 2 of SWMU-11 that would impede construction of the cap. Because a cap leaves radiologically-impacted material in place, contamination is not removed and must therefore be maintained through periodic inspections and maintenance. As a result, this option must include all the elements of Alternative 2 (LUCs).

The MicroShield computer model was used to evaluate the cap thickness requirements for the trenches at SWMU-11. Cap thickness was based upon the allowable dose of 25 mrem/yr for an industrial worker. Provisions of 10 CFR 20.1403 (Criteria for License Termination Under Restricted Conditions) requires that the annual dose to an average member of the critical group not exceed 25 mrem/yr, and that the residual radioactivity be reduced to levels that are as low as reasonably achievable (ALARA). However, unlike 10 CFR 20.1402, 10 CFR 20.1403 allows this dose limit to be achieved through the use of engineering and land use controls (LUCs), with the added requirement that the annual dose does not exceed 100 mrem/yr should those institutional controls fail or if they are no longer in effect. Since the cap is considered an engineering control that would be in place, preventing access to the waste, the 25 mrem/yr limit is considered appropriate for this analysis. Utilizing the maximum radionuclide soil concentrations at TR-5, it was determined that a cap would be required for exposure durations greater than 5.3 hours per year for an industrial worker. A cap thickness of 0.9144 meters (3 ft) would allow an industrial worker to be exposed for a duration of 11,210.8 hours per year. Calculations and a discussion to determine cap thickness can be found in **Appendix C**.

The need for a cap at TR-6 is more complex. The MicroShield computer model determined that no cap is required at TR-6 for exposure durations of 2,783 hours per year or less for an industrial worker. Current usage by a site industrial worker is estimated to be approximately 2 hours per day, 5 to 10 days per year. If site usage by an industrial worker was increased, this maximum number of hours (2,783 hours) would not be exceeded. Therefore, based on current contamination levels at TR-6, no cap is required to achieve an acceptable exposure duration for an industrial worker at TR-6. However, the sealed metal tubes at TR-6 remain a potential source of contamination should they leak. Per NCP guidance, the time factor is 1,000 years, and a potential structural decay and leak is possible in the given timeframe. Therefore, a cap is also proposed to address contamination at TR-6. This cap would meet the same design specifications and standards as that of TR-5.

As discussed in Section 7.2.3, both process options, a clay liner and a GCL cap, achieve the same outcome at a similar cost. A GCL cap, however, will provide the greatest reliability. For this reason, a cap with a GCL is retained as a process option, while a cap with a traditional clay liner is eliminated from further consideration.

8.1.4 Alternative 4: Excavation, Disposal, and Backfilling

Excavation of soil in TR-5 and TR-6 involves the physical removal of soil and/or impacted debris (i.e., metal tubes) via standard excavation practices and technology. Soil and/or debris would be transported and disposed off-site in accordance with federal and state regulations for transportation and waste disposal. Materials handling, temporary containment of soils post-excavation, confirmation soil sampling and surveying, health and safety regulations for workers inside the trenches, and the availability of clean fill dirt are all considerations. Backfilling with clean fill and topsoil, grading, and revegetation after excavation would be required.

Excavation would satisfy the RAO of preventing direct contact to or external exposure from contaminated soil and radiological debris that may pose an unacceptable risk to human health and the environment. It would also prevent further migration of the soil COCs to areas beyond the trenches, such as buffer zones surrounding the trenches, air, and groundwater.

For the Characterization Report (**Appendix A**), excavation soil waste volumes were recalculated using the overall dimensions provided by Cabrera in the Final Report (2016). For TR-5, the approximate dimensions of 46 ft long by 17 ft wide by 7 ft deep yielded a result of 203 CY instead of 194 CY. Using a bulk factor of 1.5, the waste volume was calculated as 305 CY for TR-5. For TR-6, the approximate dimensions of 40 ft long by 20 ft wide by 6 ft deep yielded a result of 178 CY instead of 165 CY. Using a bulk factor of 1.5, the waste volume was calculated as 267 CY for TR-6. The square footage of each trench was determined to be 782 ft² for TR-5 and 800 ft² at TR-6. Sloping sidewalls were not included in the current waste volume calculations but may be added in the Decision Document (DD) if this alternative is the selected remedy.

8.1.5 Alternative 5: Excavation, Sorting, Screening, and Disposal

Alternative 5, Excavation, Sorting, Screening, and Disposal of contaminated soil and debris, is similar to Alternative 4 but would apply only to the soil and debris determined to be radiologically-impacted above screening limits; material below the screening limits would be returned to the trench. Excavation of soil and debris would be removed via standard excavation practices and technology. Sorting and screening technologies would be employed on-site to determine which soil and debris were radiologically-impacted above screening limits. Impacted material would be transported offsite in accordance with federal and state regulations for transportation and waste disposal. All soil determined to be below screening limits would be returned to the trench. Materials handling, temporary containment of soils and debris post-excavation, confirmation soil sampling, and health and safety regulations for workers sorting and screening the soil and debris are all considerations. Grading and revegetation after excavation would be required.

Known debris at TR-6 is metal tubes, while at TR-5, metallic remnants from drum material are present. At TR-6, radiological contamination is primarily found in debris (i.e., metal tubes) and the amount of material above the screening limit is expected to be less than in TR-5. Due to the high cost of mobilization and demobilization of the soil screening technology, Alternative 5 would be applied to both TR-5 and TR-6 for ease of implementation and consistency. This remedial alternative would satisfy the RAO of preventing direct contact to or external exposure from contaminated soil and radiological debris that may pose an unacceptable risk to human health and the environment. It would also prevent further migration of the soil COCs to areas beyond the trenches, such as buffer zones surrounding the trenches, air, and groundwater.

8.1.6 Alternative 6: Soil Stabilization

In-situ soil treatment using cementitious solidification and stabilization, or soil stabilization, is an effective technology to treat radiological COCs. Using high-pressure concrete grouting techniques, Portland cement or acrylamide grout is injected across the target area to stabilize soil and debris within the trenches. Once the grout has solidified, migration of radionuclides is reduced. Soil stabilization would limit the potential direct contact to external exposure from radiologically-impacted soil and would reduce the potential for migration of soil COCs to areas beyond the trenches. Grouting operations do not pose significant impacts to human health or the environment due to construction or during the operational period. Emplacement of this type of in-situ treatment has proven effective to treat radiologically-impacted wastes, to provide erosion control, and reduce water infiltration.

The MicroShield computer model was used to evaluate the exposure rate reduction of in-situ grout for TR-5 and TR-6. Using the maximum radionuclide concentrations for each trench (Cabrera, 2016), a silty soil composition, a grout density of 2.35 g/cm³, and input parameters representative of each trench, a reduction in exposure rate of 30% was determined, as presented in **Appendix D**.

Currently, there are no structures or barriers at Area 2 of SWMU-11 that would impede in-situ soil stabilization. Because in-situ soil stabilization consolidates radiologically-impacted material in place, contamination is not removed and must therefore be maintained through periodic inspections and maintenance. As a result, this option must include all the elements of Alternative 2 (LUCs).

Cement grout would be injected under pressure across the target area for a combined surface area of 1,782 ft². The grout would be injected to a depth of 10 ft bgs with a radius of influence of 6 ft in diameter. Two options for grout include Portland cement and acrylamide. The Portland cement mix would be used with no additives (i.e., fly ash, cement kiln) though may include URRICHEM to increase viscosity. Acrylamide, a low-viscosity grout, would contain a composition of the following: water, acrylamide solution, potassium ferricyanide solution, triethanolamine solution, ammonium persulfate, and sodium bicarbonate (baking soda) (Long, J., Huff, D., and A. Naudts, 1997). A pilot test would be performed before injections, and real time monitoring would be performed during injections to ensure parameters such as correct porosity, density of soils, strength and viscosity of the grout, were achieved. Acrylamide grout has been shown to have a durability of more than 200 years (Long, J., Huff, D., and A. Naudts, 1997).

9 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

9.1 Evaluation Criteria

This section presents and applies evaluation criteria, as specified in 40 CFR 300.430(e)(9), to anticipated alternative performance in detailed comparative analyses of the remedial alternatives developed in the previous section. These analyses are performed to aid in the selection of a preferred remedial alternative that best satisfies the criteria identified in 40 CFR 300.430(e)(9) and the specific RAOs, ARARs, and remedial goals. Section 300.430(e)(9) of the NCP lists nine criteria against which each remedial alternative must be assessed. The acceptability or performance of each alternative against the criteria is evaluated individually so that relative strengths and weaknesses may be identified.

The first two threshold criteria must be met by each alternative:

- Protection of human health and the environment, and
- Compliance with ARARs.

The next five primary balancing criteria provide the basis for analysis:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, volume, or mass through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

State acceptance and community acceptance are modifying criteria that will be evaluated in the DD following state and public comments on the Proposed Plan (PP). These modifying criteria are not addressed in this FS.

9.1.1 Threshold Criteria

Overall Protection of Human Health and the Environment

This criterion addresses whether the remedial alternative achieves protection of human health and the environment over time considering the specific characteristics of the site. Protection of human health and the environment is met if each exposure pathway identified as potentially resulting in adverse effects is eliminated or reduced to an acceptable level or controlled through treatment or engineering and LUCs. How each alternative achieves protection over time and whether the site risks are eliminated, reduced, or controlled are also analyzed.

Compliance with ARARs

This criterion addresses whether the remedial alternative complies with federal and state environmental statutes, regulations, and other requirements that pertain to the site.

9.1.2 Balancing Criteria

Long-Term Effectiveness and Permanence

This criterion relates to long-term effectiveness of the alternative in maintaining protection of human health and the environment after response objectives have been met. The focus is on any residual risk remaining at the site after completion of the remedial action and the reliability of engineering and institutional controls and monitoring to manage hazardous substances remaining at the site.

Reduction of Toxicity, Mobility, Volume, and Mass

This criterion relates to the extent to which the remedial alternatives permanently reduce the toxicity, mobility, and volume of contaminants present at the site. Factors for this criterion include the degree of permanence of the remedial action, the amount of hazardous materials disposed offsite or destroyed/removed, and the type and quantity of residuals remaining.

Short-Term Effectiveness

Short-term effectiveness addresses the effects of the alternative during construction and implementation until the RAOs are met. This criterion considers the protection of the community and workers, including the air quality effects and hazards from excavation, transportation, and on-site treatment. In addition, the expected length of time for completion of the remedial action is considered.

Implementability

This criterion relates to the technical and administrative feasibility of the remedial alternative. The specific factors to be considered are the ability to construct, operate, and maintain the technology; the ability to monitor the effectiveness of the remedy; and the ability to obtain approvals from other agencies.

Cost

The cost estimates presented in this FS are developed to achieve a -30 percent to +50 percent accuracy range. The estimates were based on a variety of information, including generic unit costs, conventional cost estimating guides, and prior experience. Remedial Action Cost Engineering and Requirements (RACER®) software, which is widely used within the DoD and other federal agencies, was used to develop the cost estimates in this FS. The estimates have been prepared for use in the alternative evaluation based on information available at the time of the estimate. The actual costs of the project would depend on true labor and material costs, actual site conditions, final project scope, the implementation schedule, competitive market conditions, and other variable factors. The expected accuracy range of -30 percent to +50 percent is estimated over 30 years. Total cost represents the rounded present worth value considering a discount rate of 1.5 percent for 30 years, based on the Office of Management and Budget (OMB) Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (OMB, 2018). Contingencies have been applied to each alternative to take into consideration assumptions and uncertainties associated with the current project scope and unforeseen circumstances. A 30 percent contingency allowance was used to reflect uncertainties unless otherwise noted. Costs are rounded to the nearest \$1,000 per EPA guidance.

9.1.3 Modifying Criteria

State Acceptance

This criterion evaluates the technical and administrative issues and concerns the State of Utah may have regarding each of the alternatives. This criterion will be addressed in the DD once comments on the FS and PP have been received.

Community Acceptance

This criterion evaluates the issues and concerns the public may have regarding each of the alternatives. As with State Acceptance, this criterion will be addressed in the DD once comments on the FS and PP have been received.

9.2 Individual Alternative Analysis

The six individual alternatives, including the No Action alternative, will be evaluated in accordance with the seven criteria specified in Sections 9.1.1 and 9.1.2.

9.2.1 Alternative 1 – No Action

Alternative 1 leaves the trenches in Area 2 of SWMU-11 in their present condition with no LUCs or remedial actions. Radiologically-impacted soils and debris would remain as they currently exist in TR-5 and TR-6. Because contaminated media would be left on the site, a review of the site conditions would be required every 5 years, as specified in the NCP.

Alternative 1 serves as the baseline against which the effectiveness of other alternatives is evaluated and is included per the NCP. **Table 7** presents a summary of Alternative 1 evaluated against the seven criteria presented below.

Overall Protection of Human Health and the Environment

Alternative 1 provides no protection to human health and the environment nor does it monitor impacted media or document land uses to ensure protection of human health and the environment. The No Action Alternative does not reduce or control potential radiological exposure to soil or debris. Impacted soil and debris would not be removed, reduced, or controlled through treatment, engineering, and/or LUCs.

Compliance with ARARs

ARARs are not met with the No Action alternative, as no remedy would be implemented.

Long-Term Effectiveness and Permanence

The No Action alternative does not provide any controls for addressing reduction of radiological COCs over time aside from natural radioactive decay, reduction of radiological exposure, or the long-term management of impacted media; therefore, the No Action alternative does not meet this criterion.

Reduction of Toxicity, Mobility, Volume, and Mass

The No Action alternative does not employ any treatment that would reduce the toxicity, mobility, volume, or mass of impacted material; therefore, the No Action alternative does not meet this criterion.

Short-Term Effectiveness

The No Action alternative does not pose any additional risks to the community, site industrial workers, or the environment since there are no remedial activities associated with it; however, it does not mitigate any existing or potential future risks/hazards.

Implementability

Alternative 1 has no action to implement, in that no action would be taken.

Cost

There are no present worth costs and capital costs for the No Action alternative because no action would be taken.

9.2.2 Alternative 2 – Land Use Controls

Alternative 2 includes institutional and engineering controls. Fencing and signage would be the primary LUCs employed at Area 2 of SWMU-11. The LUCs would be kept in place until UU/UE could be achieved. DPG encompasses Area 2 of SWMU-11, which is currently owned and operated by the DoD. Thus, implementation of this remedy does not require the approval or participation of landowners or private individuals. Because DPG is an active military installation, the local authority for regulating and enforcing ICs is the Garrison Manager. Therefore, DPG installation personnel will incorporate enforceable restrictions into the Base Master Plan, instructions, and orders used by the Garrison Manager to govern conduct, actions and activities on the installation.

 Table 7 presents a summary of Alternative 2 evaluated against the seven criteria presented below.

Overall Protection of Human Health and the Environment

Alternative 2 provides a low level of protection to human health by reducing the potential for radiological exposure in soil and debris. However, radiologically-impacted materials would not be eliminated or reduced, and the impact on the environment remains the same. Fencing would serve to create a physical barrier around the trenches, thus reducing the potential for exposure to radiological soil and debris, and to prevent inadvertent access to the trenches. Signage would inform potential receptors of the restricted land use and potential exposure to radiologically-impacted media.

Current receptors at Area 2 of SWMU-11 are identified as site industrial workers. Although DPG is a federal facility and site access is already restricted, the fencing and signage provide additional limitations to the trenches by the current receptors. Site industrial workers may not be aware of the current potential exposure hazards that exist at the trenches. Additionally, if a trespasser or other human receptor was present, fencing and signage would serve to reduce the potential for exposure. Fencing requirements are a 3-strand wire, thus allowing predators into the area. This is not a concern because ecological receptors were determined to not be at risk of exposure, given the current pathways. Overall, Alternative 2 adds a degree of protection to human health and environment.

Compliance with ARARs

Chemical-specific ARARs were identified as Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402) and Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403). LUCs would comply with the chemical-specific ARARs for Restricted (Industrial) (10 CFR 20.1403) use.

Location-specific ARARs were identified as the Archaeological and Historic Preservation Act, the Migratory Birds Act, and the Bald and Golden Eagle Protection Act. Additional chemical- and action-specific ARARs described in Section 6.2 may need to be taken into consideration. Planning will be required to comply with all chemical-, location-, and action-specific ARARs.

Long-Term Effectiveness and Permanence

Radiologically-impacted soil and debris would remain in the trenches and the risk of human receptor exposure through potentially complete pathways (i.e., direct radiation, inhalation of re-suspended dust, and direct ingestion of soil) would remain indefinitely. Alternative 2 does provide some level of long-term effectiveness and permanence through the use of LUCs. Posted signs should alert human receptors of the risks associated with potential radiological exposure, and fencing should offer some level of protection by restricting access to the trenches. However, an on-site land manager would not be present to ensure that engineering controls are effective. Periodic maintenance would be required to maintain the integrity of fencing and signs around the trenches.

Reduction of Toxicity, Mobility, Volume, and Mass

Alternative 2 does not provide a reduction in toxicity, mobility, volume, or mass, and radiological COCs would remain in soil and debris.

Short-Term Effectiveness

Construction activities for installation of fencing and signage are estimated to take less than 1 week to complete. A truck used to transport fencing and signage materials should have no impact on site traffic flow. Installation of fencing and signage should not require extensive planning due to the size of the site and trenches. Fencing and signs would be placed around the perimeter of the trenches at an adequate distance such that there would be no potential for construction workers to come in contact with impacted soils. Any short-term risks to workers would be limited through the implementation of an approved health and safety plan and additional monitoring support during construction field activities, if deemed necessary. Potential environmental impacts would be addressed in the planning documents for this alternative and are considered to be minimal.

Implementability

Alternative 2 is considered technically feasible, and services and materials should be readily available. If LUCs are selected as a remedial action, and prior to implementation, provisions for legally enforceable ICs will be fully defined in the Remedial Design and detailed in a Land Use Control Implementation Plan (LUCIP), both of which would be prepared and submitted to the Army and NRC before LUCs could proceed. Additional documents would include a DD and PP.

Alternative 2 construction activities (i.e., fence and sign installation) would be easy to implement due to the amount of construction materials required and the size of TR-5 and TR-6 (approximately 782 ft² and 800 ft², respectively). Due to the size of the trenches, fencing could be installed around both trenches as one area, or around the trenches individually. Fencing would need to be 3-strand wire, as a chain-link fence would preclude predators from entering the site and allow burrowing animals to contact soil and debris within the trenches. Signs would be installed at access points and around the entire perimeter of Area 2 of SWMU-11. Installation is anticipated to take approximately 1 to 2 days, with a 2- to 3-person crew, depending on any site-specific requirements.

Although the work area has limited access, all site industrial workers and materials necessary to implement the engineering controls should be readily available through the site contractor and identified prior to construction activities. Health and safety protocols would need to be identified prior to

construction activities to ensure a safe working environment for the industrial workers. Periodic maintenance by site industrial workers would be required to maintain the integrity of fencing and signs around the trenches.

Administratively, implementation of Alternative 2 would require documentation and planning meetings. Documentation would include a Remedial Design, a LUCIP, a DD, a PP, and a Site-Specific Final Report. ICs would be fully defined in the Remedial Design and a LUCIP would be prepared detailing ICs prior to beginning installation activities. A Site-Specific Final Report would be prepared to document the completed remedial action. All land associated with TR-5 and TR-6 is part of DPG and is currently owned and operated by the DoD. Thus, implementation of this remedy does not require the approval or participation of landowners or private individuals. At DPG, ICs would be regulated and enforced by the Garrison Manager, and LUCs would be addressed in the Base Master Plans and separate MoU.

Cost

The cost estimate for implementation of LUCs for a 30-year timeframe was evaluated using RACER[®] software. This estimate includes a LUCIP and other associated documentation, implementation of site use controls, planning meetings, access control signage, annual site inspections, and fencing costs for 3-strand wire fence. The total estimated cost for Alternative 2 is \$167,000.

Appendix E and **Table 8** provide a comprehensive breakdown of these costs, including capital costs, annual O&M costs, periodic costs, and the total present values of the alternatives. Although the remedy is expected to be in place longer than 30 years (1,000 years per NCP guidance), cost estimates are provided in this FS for a 30-year timeframe.

9.2.3 Alternative 3 - Capping

Under Alternative 3, capping would provide containment of radiologically-impacted soil within TR-5 and TR-6 and would be implemented in conjunction with LUCs.

 Table 7 presents a summary of Alternative 3 evaluated against the seven criteria presented below.

Overall Protection of Human Health and the Environment

Capping of TR-5 and TR-6 at Area 2 of SWMU-11 would achieve RAOs by providing a physical barrier capable of eliminating direct contact to or exposure by current and future receptors from radiologically-impacted soil. Capping would also reduce the potential for migration of soil COCs. However, radiologically-impacted materials would not be eliminated or reduced, and the impact on the environment remains the same. Alternative 3 would be implemented in conjunction with LUCs, which would serve to further limit exposure to impacted material. The caps would be protective of human health and the environment.

Compliance with ARARs

Alternative 3 would comply with chemical-, location-, and action-specific ARARs for soil.

The MicroShield model was used to determine a protective cap thickness based on an allowable dose of 25 mrem/yr for the industrial worker (**Appendix C**). Therefore, Alternative 3, used in conjunction with LUCs, would comply with chemical-specific ARARs.

Location-specific ARARs (identified as the Archaeological and Historic Preservation Act, the Migratory Birds Act, and the Bald and Golden Eagle Protection Act) would require planning and compliance by capping activities and LUCs. Additional chemical- and action-specific ARARs described in Section 6.2 may also need to be taken into consideration.

Long-Term Effectiveness and Permanence

Alternative 3 would achieve long-term effectiveness and permanence through implementation of a GCL cap at TR-5 and TR-6 combined with LUCs. GCL caps and LUCs (i.e., fencing, signage, and land use restrictions) would provide erosion control as well as an effective and reliable long-term exposure barrier for industrial workers. The caps would require routine maintenance and inspection by a work crew.

Reduction of Toxicity, Mobility, Volume, and Mass

Alternative 3 would permanently reduce the mobility of radiological COCs in soil through erosion and surface water control. However, the toxicity, volume, and mass of radiological COCs in soil would not be reduced.

Short-Term Effectiveness

Implementation of a GCL cap for both trenches, combined with LUCs, would result in an immediate reduction in potential exposure to site industrial workers.

Implementability

Installation of GCL caps and LUCs is technically feasible, and services and materials for both should be readily available. A GCL cap is a common technology and can be designed to specification. Fencing and signage, described in Section 9.2.2, can be obtained by site industrial workers. Prior to installation and implementation, provisions for legally enforceable ICs will be fully defined in the Remedial Design and detailed in a LUCIP, both of which would be prepared and submitted to the Army and NRC before work could proceed. Additional documents would include a DD and PP.

Alternative 3 construction activities would include the design and construction of two GCL caps. Each cap, a RCRA hazardous waste cap GCL, would provide a protective cover of a minimum of 3 ft and be constructed of 40-millimeter high-density polyethylene (HDPE) geomembrane. The total area would be designed to cover TR-5 and TR-6 individually, although it could be expanded to cover both trenches, if determined appropriate.

Construction material for LUCs (i.e., fencing and signage) at both trenches is available. Due to the size of the trenches, fencing could be installed around both trenches as one area, or around the trenches individually. Although the work area has limited access, all site industrial workers and materials necessary to implement the GCL caps and LUCs should be identified prior to construction activities. Health and safety protocols would need to be identified prior to beginning construction activities to ensure a safe working environment for the industrial workers during installation. To document the completed remedial action, a Site-Specific Final Report would be prepared. Periodic maintenance by site industrial workers would be required to maintain the integrity of the GCL caps. Cap maintenance does not require radiation-specific training by industrial workers if they do not breach the HDPE layer.

Administratively, implementation of Alternative 3 would require documentation and planning meetings. Documentation would include a Remedial Design, a LUCIP, a DD, a PP, and a Site-Specific Final Report. ICs would be fully defined in the Remedial Design and a LUCIP would be prepared detailing ICs prior to beginning installation activities. A Site-Specific Final Report would be prepared to document the completed remedial action. All land associated with TR-5 and TR-6 is part of DGP and is currently owned and operated by the DoD. Thus, implementation of this remedy does not require the approval or participation of landowners or private individuals. At DPG, ICs would be regulated and enforced by the Garrison Manager, and LUCs would be addressed in the Base Master Plans and separate MoU.

Cost

The cost estimate for implementation of a GCL cap at TR-5 and TR-6 and LUCs for a 30-year timeframe was evaluated using RACER[®] software. This estimate includes two RCRA Hazardous Waste Cap GCL built to specification, a LUCIP and other associated documentation, planning meetings, access control signage, annual site inspections, and engineering controls. The total estimated cost for Alternative 3 is \$383,000.

Appendix E and **Table 8** provide a comprehensive breakdown of these costs, including capital costs, annual O&M costs, periodic costs, and total present value of Alternatives 3. The costs associated with Alternative 2, LUCs, are incorporated into this estimate. Although the remedy is expected to be in place longer than 30 years (1,000 years per NCP guidance), cost estimates are provided in this FS for a 30-year timeframe.

9.2.4 Alternative 4 – Excavation, Disposal, and Backfilling

Under this alternative, the physical removal of radiologically-impacted soils and debris, off-site disposal, and backfilling with clean fill and topsoil would be implemented. The following discussion and evaluation apply to both TR-5 and TR-6.

 Table 7 presents a summary of Alternative 4 evaluated against the seven criteria presented below.

Overall Protection of Human Health and the Environment

Excavation of radiologically-impacted soil and debris in TR-5 and TR-6 would achieve RAOs by preventing direct contact to or external exposure from contaminated soil and radiological debris that may pose an unacceptable risk to human health and the environment. It would also prevent further migration of the soil COCs to areas beyond the trenches, such as buffer zones surrounding the trenches, air, and groundwater. Alternative 4 would thereby protect against both current and future human exposure to soil and would be protective of human health and the environment.

Compliance with ARARs

Alternative 4 would comply with chemical-, location-, and action-specific ARARs for soil.

Chemical-specific ARARs were identified as Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402) and Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403). The soil DCGLs for the residential receptor (unrestricted) use are provided in **Table 4**. Excavation of soil and debris will achieve UU/UE and would therefore comply with chemical-specific ARARs.

Location-specific ARARs were identified as the Archaeological and Historic Preservation Act, the Migratory Birds Act, and the Bald and Golden Eagle Protection Act. Action-specific ARARs were identified as those that address the transfer for disposal and manifest of low-level radioactive waste, temporary on-site storage of waste, staging piles, and land disposal restrictions. These ARARs would be required during the loading, marking, and manifesting of impacted soils and debris. Additional chemical-and action-specific ARARs described in Section 6.2 may need to be taken into consideration. Planning will be required to comply with all chemical-, location-, and action-specific ARARs.

Long-Term Effectiveness and Permanence

Alternative 4 would achieve long-term effectiveness and permanence through the physical removal of radiologically-impacted soil and debris from TR-5 and TR-6.

Reduction of Toxicity, Mobility, Volume, and Mass

Alternative 4 would permanently reduce the toxicity, mobility, volume, and mass of radiological COCs via the physical removal of impacted soil and debris.

Short-Term Effectiveness

Implementation of Alternative 4 would be immediately effective upon excavation of impacted soil and debris; however, removal activities may result in minimal exposure risks to the construction/industrial workers via the release of fugitive dusts and runoff from disturbed soil. Dust controls may include water sprays or application of chemical dust suppressants. Surface water controls may also be required.

Implementability

Alternative 4 is technically implementable via standard excavation practices and technology. Excavation can easily be performed, and typical equipment used may include backhoes, drag lines, clamshells, and vacuum trucks. Excavator services are readily available, as are the services and materials necessary for the transportation of excavated soil and debris to an approved off-site disposal facility or landfill.

Materials handling must be considered in the implementation of excavation. Staging areas would be used to prepare impacted soil and debris for disposal and transport; this area would be graded to reduce the potential for ponding and collapse of trench walls, lined to prevent groundwater contamination, and bermed to prevent runoff. The off-site transportation of wastes resulting from excavation must meet Federal and State of Utah shipping and manifesting regulations. Excavated soil and debris would be transported to an approved landfill for disposal. The excavated area would be backfilled with clean soil, and a local fill dirt location may be available. Backfilling, grading, and revegetation after excavation are necessary to prevent stormwater runoff and erosion.

To ensure excavation was completed to meet unrestricted (residential) standards, or UU/UE, confirmation soil sampling and a magnetometer survey or use of a FIDLER or GM probe would be performed following excavation to ensure all radiologically-impacted materials had been removed. The extent of each trench has previously been evaluated and the general dimensions and extent of contamination within each individual trench are known.

While excavation and disposal of impacted soil and debris eliminates the environmental and health concerns associated with direct contact of radiologically-impacted soil and debris, consideration must be given to the health and safety of site industrial/remedial workers. On-site air monitoring and dust and vapor control provisions would be necessary during excavation operations. Excavation activities can result in the release of fugitive dusts and runoff from disturbed soil. Dust controls could include water sprays or application of chemical dust suppressants. Surface water controls may also be required. Excavation at Area 2 of SWMU-11 would create minimal disturbance of the overall operational activities of the surrounding facilities.

Cost

The cost estimate for implementation of excavation, disposal, and backfilling was evaluated using RACER[®] software. This estimate includes the total excavation of both trenches, temporary containment for storage of excavated materials, confirmation soil sampling, backfilling, trench restoration, and transportation to a local facility. The total estimated cost for Alternative 4 is \$593,000.

Appendix E and Table 8 provide a comprehensive breakdown of these costs, including capital costs and total present values of the alternatives.

9.2.5 Alternative 5 – Excavation, Sorting, Screening, and Disposal

Alternative 5 involves the physical removal of soil and debris from both trenches, sorting and screening of radiologically-impacted material from non-radiologically impacted material, off-site disposal of impacted material, and backfilling with non-impacted soils. The primary difference between Alternative 5 and Alternative 4 is that Alternative 5 would incorporate a sorting and screening phase to process impacted soil and debris on-site.

 Table 7 presents a summary of Alternative 5 evaluated against the seven criteria presented below.

Overall Protection of Human Health and the Environment

Excavation of radiologically-impacted soil and debris would achieve RAOs by preventing direct contact to or external exposure from contaminated soil and radiological debris that may pose an unacceptable risk to human health and the environment. It would also prevent further migration of the soil COCs to areas beyond the trenches, such as buffer zones surrounding the trenches, air, and groundwater. Alternative 5 would thereby protect against both current and future human exposure to soil and would be protective of human health and the environment.

Compliance with ARARs

Alternative 5 would comply with chemical-, location-, and action-specific ARARs for soil.

Chemical-specific ARARs were identified as Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402) and Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403). The soil DCGLs for the residential receptor (unrestricted) use are provided in **Table 4**. Excavation of impacted soil and debris from the trenches will achieve UU/UE and would therefore comply with chemical-specific ARARs.

Location-specific ARARs were identified as the Archaeological and Historic Preservation Act, the Migratory Birds Act, and the Bald and Golden Eagle Protection Act. Action-specific ARARs were identified as those that address the transfer for disposal and manifest of low-level radioactive waste, temporary on-site storage of waste, staging piles, and land disposal restrictions. These ARARs would be required during the loading, marking, and manifesting of impacted soils and debris. Additional chemical-and action-specific ARARs described in Section 6.2 may need to be taken into consideration. Planning will be required to comply with all chemical-, location-, and action-specific ARARs.

Long-Term Effectiveness and Permanence

Alternative 5 would achieve long-term effectiveness and permanence through the physical removal of radiologically-impacted soil and debris from the trenches.

Reduction of Toxicity, Mobility, Volume, and Mass

Alternative 5 would permanently reduce the toxicity, mobility, volume, and mass of radiological COCs via the physical removal of impacted soil and debris from the trench.

Short-Term Effectiveness

Implementation of Alternative 5 would be immediately effective upon excavation of impacted soil and debris; however, removal activities may result in minimal exposure risks to the construction/industrial workers via the release of fugitive dusts and runoff from disturbed soil. Dust controls may include water sprays or application of chemical dust suppressants. Surface water controls may also be required.

Implementability

Alternative 5 is technically implementable via standard excavation practices and technology. Excavation can easily be performed, and typical equipment used may include a backhoe and vacuum truck. Excavator services are readily available, as are the services and materials necessary for the transportation of excavated soil and debris to an approved off-site disposal facility or landfill. However, the technology used for sorting and screening of soils and debris may be less feasible.

As with Alternative 4, materials handling must be considered. Staging areas would be used to prepare impacted soil and debris for on-site radiological screening and processing, disposal, and transport. The staging area would be graded to reduce ponding and collapse of trench walls, lined to prevent groundwater contamination, and bermed to prevent runoff. The off-site transportation of wastes resulting from excavation must meet Federal and State of Utah shipping and manifesting regulations. Excavated soil and debris would be transported to an approved disposal facility. The excavated area would be backfilled with non-impacted soil and clean backfill, if required, and non-impacted material would be returned to the trench. Backfilling, grading, and revegetation after excavation are necessary to prevent stormwater runoff and erosion.

To ensure excavation was completed to meet unrestricted (residential) standards, or UU/UE, confirmation soil sampling and a magnetometer survey or use of a FIDLER or GM probe would be performed following excavation to ensure all radiologically-impacted materials above the screening limits had been removed. The extent of each trench has previously been evaluated and the general dimensions and extent of contamination within each individual trench are known.

While excavation and disposal of impacted soil and debris eliminate the environmental and health concerns associated with direct contact of radiologically-impacted soil and debris, consideration must be given to the health and safety of site industrial/remedial workers. On-site air monitoring and dust and vapor control provisions would be necessary during excavation operations. Excavation activities can result in the release of fugitive dusts and runoff from disturbed soil. Dust controls could include water sprays or application of chemical dust suppressants. Surface water controls may also be required. Excavation at Area 2 of SWMU-11 would create minimal disturbance of the overall operational activities of the surrounding facilities.

The technology used to sort and screen impacted soils and debris will be transported from an off-site location and will incur a high mobilization/demobilization cost (Section 9.2.5). On-site radiological screening involves the pre-treatment of soils and debris by screening and tilling, followed by the processing of all materials. Implementing sorting and screening of soils to separate radiologically-impacted materials from non-radiologically impacted materials may not be feasible given that the same outcome (unrestricted residential use) is achieved with Alternative 4 at a lower cost. Development of this comparison is made in Section 9.3.6.

Cost

The cost estimate for implementation of excavation, sorting, screening, and disposal was evaluated using RACER[®] software. This estimate includes the mobilization and demobilization of soil screening technology, total excavation of both trenches, temporary containment for storage of excavated materials, confirmation soil sampling, backfilling, trench restoration, on-site radiological screening and processing, and transportation to a local facility. The total estimated cost for Alternative 5 is \$1,439,000.

Appendix E and Table 8 provide a comprehensive breakdown of these costs, including capital costs and total present values of the alternatives.

9.2.6 Alternative 6 – Soil Stabilization

Under Alternative 6, in-situ soil stabilization using cement or acrylamide grouting techniques would provide containment of radiologically-impacted soil and debris within TR-5 and TR-6 and would be implemented in conjunction with LUCs.

Table 7 presents a summary of Alternative 6 evaluated against the seven criteria presented below.

Overall Protection of Human Health and the Environment

Soil stabilization through the injection of cement or acrylamide grout at TR-5 and TR-6 would achieve RAOs by limiting direct contact to or exposure by current and future receptors from radiologicallyimpacted soil. Soil stabilization would also reduce the potential for migration of soil COCs. However, radiologically-impacted materials would not be eliminated or reduced. Alternative 6 would be implemented in conjunction with LUCs, which would serve to further limit exposure to impacted material. Soil stabilization would protect against both current and future human exposure to soil and would be protective of human health and the environment.

Compliance with ARARs

Alternative 6 would comply with chemical-, location-, and action-specific ARARs for soil.

Chemical-specific ARARs were identified as Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402) and Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403). In-situ stabilization of soil and debris would be used in conjunction with LUCs (Alternative 2) to comply with the chemical-specific ARARs for Restricted (Industrial) (10 CFR 20.1403) use.

Location-specific ARARs were identified as the Archaeological and Historic Preservation Act, the Migratory Birds Act, and the Bald and Golden Eagle Protection Act. Additional chemical- and action-specific ARARs described in Section 6.2 may need to be taken into consideration. Planning will be required to comply with all chemical-, location-, and action-specific ARARs.

Long-Term Effectiveness and Permanence

Alternative 6 would achieve long-term effectiveness and permanence through cement or acrylamide grouting of soil and debris at TR-5 and TR-6. Acrylamide grout has shown to have durability of more than 200 years. LUCs (i.e., fencing, signage, and land use restrictions) would provide erosion control as well as an effective and reliable long-term exposure barrier for industrial workers. The stabilized material would require routine maintenance and inspection by a work crew.

Reduction of Toxicity, Mobility, Volume, and Mass

Alternative 6 would permanently reduce the mobility of radiological COCs in soil through erosion and surface water control, and by reducing water infiltration. However, the toxicity, volume, and mass of radiological COCs in soil would not be reduced.

Short-Term Effectiveness

Implementation of soil stabilization through cement or acrylamide grouting for both trenches, combined with LUCs, would result in an immediate reduction in potential exposure to site industrial workers. However, injection activities may result in minimal exposure risks to the industrial workers via the release of fugitive dusts and runoff from disturbed soil. Dust controls may include water sprays or application of chemical dust suppressants. Surface water controls may also be required.

Implementability

Injection of grout for soil stabilization is technically feasible, and services and materials should be generally available. In-situ soil stabilization is a commonly used technique for the treatment of hazardous waste and low-level radioactive waste. Cementitious materials are the predominant materials of choice because of their low associated processing costs and are considered environmentally friendly. Fencing and signage, described in Section 9.2.2, can be obtained by site industrial workers. Prior to installation and implementation, a LUCIP would be prepared and submitted to the Army and NRC before work could proceed. Additional documents would include a DD and PP.

Alternative 6 injection activities would include high pressure injection of Portland cement or acrylamide grout into TR-5 and TR-6 to a depth of approximately 10 ft bgs covering an approximate are of 1,782 ft². The radius of influence would be 6 ft in diameter. Prior to grouting, a trial grouting or pilot test may be conducted on a small-scale to confirm that the design objectives could be met and to make the necessary adjustment to grouting procedures, equipment, grout mix, injection pressures, injection sequence, and waste management. Grouting operations would be monitored and assessed in real time using geotechnical testing to ensure proper construction, porosity, density of soils, strength and viscosity of the grout.

Construction material for in-situ soil stabilization would include equipment which would install grouting rods and perform high-pressure injections, and equipment for mixing, spreading, and compacting. Post-installation, the stabilized mass may be subject to compressive strength and durability testing. Stabilized grout would need to pass freeze/thaw and wet/dry testing. The recommended NRC test requires testing without controlling humidity, allowing drying of the grout at the highest temperature.

Construction material for LUCs (i.e., fencing and signage) at both trenches is available. Due to the size of the trenches, fencing could be installed around both trenches as one area, or around the trenches individually. Although the work area has limited access, all site industrial workers and materials necessary to implement soil stabilization and LUCs should be identified prior to construction activities. Health and safety protocols would need to be identified prior to beginning construction activities to ensure a safe working environment for the industrial workers during installation.

While injection of impacted soil and debris eliminates the environmental and health concerns associated with direct contact of radiologically-impacted soil and debris, consideration must be given to the health and safety of site industrial workers. On-site air monitoring and dust and vapor control provisions would be necessary during injection operations. Injection activities can result in the release of fugitive dusts and runoff from disturbed soil. Dust controls could include water sprays or application of chemical dust suppressants. Surface water controls may also be required. However, injection activities at Area 2 of SWMU-11 would create minimal disturbance of the overall operational activities of the surrounding facilities.

To document the completed remedial action, a Site-Specific Final Report would be prepared. Periodic maintenance by site industrial workers may be required to ensure the condition of the grout is maintained (i.e., cracking), in addition to maintaining the integrity of fencing and signs around the trenches.

Administratively, implementation of Alternative 6 would require documentation and planning meetings. All land associated with TR-5 and TR-6 is currently owned and operated by the DoD. Thus, implementation of this remedy does not require the approval or participation of landowners or private individuals. For active bases, LUCs are commonly addressed through remedy selection documents, base master plans, and separate MoUs.

Cost

The cost estimate for grout injection at TR-5 and TR-6 and LUCs for a 30-year timeframe was evaluated using RACER[®] software. This estimate includes high-pressure injection of grout, a pilot test and geotechnical testing, a LUCIP and other associated documentation, planning meetings, access control signage, periodic site inspections, and engineering controls. The total estimated cost for Alternative 6 is \$487,000.

Appendix E and **Table 8** provide a comprehensive breakdown of these costs, including capital costs, annual O&M costs, periodic costs, and total present value of Alternatives 6. The costs associated with Alternative 2, LUCs, are incorporated into this estimate. Although the remedy is expected to be in place longer than 30 years (1,000 years per NCP guidance), cost estimates are provided in this FS for a 30-year timeframe.

9.3 Comparative Alternative Analysis

9.3.1 Overall Protection of Human Health and the Environment

The remedial technologies that provide the greatest overall protection of human health and the environment are Alternatives 4 and 5. Through removal of radiologically-impacted soil and debris from the trenches, UU/UE is achieved immediately and has long-term effectiveness and permanence.

Alternatives 2, 3, and 6 do not achieve UU/UE and contamination is not eliminated or reduced. Alternative 1 does not provide additional protection of human health and the environment.

9.3.2 Compliance with Applicable or Relevant and Appropriate Requirements

The chemical-specific ARARs for Radiological Criteria for Unrestricted Use (Residential) (10 CFR 20.1402) are achieved through Alternatives 4 and 5. Location- and action-specific ARARs are also met with these two remedial alternatives. Alternatives 2, 3, and 6 do, however, comply with the ARAR Criteria for License Termination Under Restricted Conditions (Industrial) (10 CFR 20.1403).

9.3.3 Long-Term Effectiveness and Permanence

Alternatives 4 and 5 would achieve long-term effectiveness and permanence through the physical removal of radiologically-impacted soil and debris from TR-5 and TR-6.

While Alternatives 2, 3, and 6 do provide a level of long-term effectiveness and permanence through LUCs, GCL caps, and soil stabilization, respectively, radiologically-impacted soil and debris would remain in the trenches indefinitely. With Alternative 2, the risk of human receptor exposure through potentially complete pathways (i.e., direct radiation, inhalation of re-suspended dust, and direct ingestion of soil) would also remain.

The No Action alternative does not meet this criterion.

9.3.4 Reduction of Toxicity, Mobility, Volume, and Mass

Alternatives 4 and 5 would permanently reduce the toxicity, mobility, volume, and mass of radiological COCs via the physical removal of impacted soil and debris.

Though Alternatives 3 and 6 would reduce the mobility of radiological COCs in soil, the toxicity, volume, and mass would not be reduced. Similarly, Alternative 2 does not provide a reduction in toxicity, mobility, volume, or mass nor is mobility of COCs impeded.

The No Action alternative does not meet this criterion.

9.3.5 Short-Term Effectiveness

Alternatives 3, 4, 5, and 6 would result in an immediate reduction in potential exposure to site industrial workers and the environment. The potential for exposure by site industrial workers to radiologically-impacted materials is possible during the implementation of all three alternatives. However, the exposure is expected to be less in Alternative 3 and 6 than the potential exposure of an industrial worker in Alternatives 4 and 5.

Alternative 2 is effective upon installation of fencing and signage, though the effectiveness is substantially less than in Alternatives 3, 4, 5, and 6. Alternative 1 does not mitigate any existing or future risks or hazards.

9.3.6 Implementability

Alternative 1 is the most easily implemented alternative as there are no required actions.

Compared to Alternatives 3, 4, 5, and 6, Alternative 2 is considered easily implementable and involves the fewest industrial workers, the shortest construction and implementation time, and the fewest materials. Administratively, it is the easiest to complete, as compared with the other remaining alternatives.

Alternatives 3, 4, 5, and 6 require a larger number of industrial workers, health and safety monitoring, and more materials to implement. For these three alternatives, services, personnel, and materials are generally readily available but require greater coordination and planning. Health and safety protocols would need to be identified prior to construction activities to ensure a safe working environment for the industrial workers during remedy implementation could begin. Alternatives 3 and 6 require periodic maintenance by site workers to maintain the integrity of the caps and grouted trenches.

Alternatives 4 and 5 require the highest level of implementation. Both require adherence to federal and state disposal and transportation regulations. Heavy equipment used for excavation and backfilling, as well as staging areas and trench specification, would be used. Confirmation soil sampling and radiological scans would also be required. Backfilling, grading, and revegetation following excavation would be necessary.

Alternative 5 would require the use of additional technologies for soil and debris sorting and screening. These technologies would require transport from a greater distance and come at a higher cost. Mobilization and demobilization costs are considerable. On-site radiological screening involves the pre-treatment of soils and debris by screening and tilling, followed by processing all materials. This would require additional time and labor. Of all alternatives, Alternative 5 is the least implementable.

9.3.7 Cost

The total estimated costs for implementing the alternatives at TR-5 and TR-6 are included in **Table 8**. These costs were obtained from the Basis of Cost Estimates presented in **Appendix E**. Cost-specific breakdowns of line items are also provided in the Folder Assembly Level Data Report in **Appendix E**. The capital and O&M cost breakdown for each alternative, if applicable, is provided below:

- Alternative 1 (No Action) No associated capital, O&M, or periodic costs.
- Alternative 2 (LUCs) Capital costs include labor and materials for the installation of fencing and signage and implementation of LUCs by the DoD. Annual O&M costs include annual site inspections and multiple 5-year reviews. Periodic costs include site inspection and maintenance, administrative documentation, planning, meetings, and five-year reviews.
- Alternative 3 (GCL Capping) Capital costs include labor and materials for design, construction, and installation of the GCL caps. Capital costs also include labor and materials for the installation of fencing and signage and implementation of LUCs by the DoD. Annual O&M costs include annual site inspections. Periodic costs include site inspection and maintenance, administrative documentation, planning, meetings, and five-year reviews.
- Alternative 4 (Excavation, Disposal, and Backfilling) Capital costs include labor and materials to excavate the trenches, set up containment areas, perform confirmation soil sampling, backfill with clean fill dirt, transport impacted-materials off-site, and restore the surface with native vegetation. Costs also include administrative documentation, planning, and meetings.
- Alternative 5 (Excavation, Sorting, Screening, and Disposal) Capital costs include the mobilization and demobilization of soil screening technology, labor and materials to excavate the trenches, set up containment areas, perform pre-treatment of the soils by screening, process all materials, perform confirmation soil sampling, backfill with clean fill dirt, transport impacted-materials off-site, and restore the surface with native vegetation. Costs also include administrative documentation, planning, and meetings.
- Alternative 6 (Soil Stabilization) Capital costs include labor and materials for high-pressure grouting of the trenches, and QC and geotechnical testing. Capital costs also include labor and materials for the installation of fencing and signage and implementation of LUCs by the DoD. O&M and periodic costs include site inspection and maintenance, administrative documentation, planning, meetings, and five-year reviews.

10 SUMMARY AND CONCLUSION

The six remedial alternatives presented in this FS are developed, screened, and evaluated to address siterelated contaminants determined to pose an unacceptable risk to human health and the environment. The remedial alternatives are evaluated based on the nature and extent of contamination, the ability to satisfy RAOs and achieve remedial goals, and compliance with chemical-, location, and action-specific ARARs. Remedial technologies are identified and screened through evaluation criteria for an individual and comparative analysis. The selected remedy alternative will be determined based upon the outcome of the PP. This page intentionally left blank

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TABLES

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Table 1, 11 C and 11 C 2005 Thase 11 Investigation Results.							
Gamma Exposure Rate Measurements							
Trench	Result (µR/hr) Center of Trench	Result (µR/hr) 3 ft from Center	Result (μR/hr) 6 ft from Center				
TR-5	420	50	30				
FIDLER and GM Pancake Probe - Gamma and Beta Measurements							
Trench	Result (cpm) Directly Over Area	Background Radiation Levels FIDLER Results (cpm)	Background Radiation Levels GM Probe Results (cpm)				
TR-5	1,200 - 575,000	25,000 - 28,000	75 - 125				
Material Samples							
Trench	Notes	Depth	Result				
TR-6 (MS02)	Solidified sand from inside a corroded drum	6 ft bgs	No detectable levels of radioactivity				
TR-6 (MS03)	Multiple buried metal tubes	NA	Sample not sent to laboratory, remains on site. Gamma radiation signature similar to Cesium-137				
TR-5 (MS04 & MS04A)	Metal remnants of drum material	0.5 ft bgs	Radioactivity primarily due to Strontium-90 (results on following Table 1)				

Table 1, TR-5 and TR-6 2005 Phase II Investigation Results.

Notes:

 $\mu R/hr$ - microroentgen per hour

ft - feet

FIDLER - Field Instrument for the Detection of Low Energy Radiation

GM - Geiger Mueller

cpm - counts per minute MS - Material Sample

bgs - below ground surface

NA - isotopic analysis not used with background samples

Table 1 Analytical Results, TR-5 Sample MS04/04A Radiological Survey SWMU-11 Final Phase II RCRA Facility Investigation Report Addendum Dugway Proving Ground, Utah

Radionuclide	Analysis	Result	Uncertainty	MDL			
of Concern	Analysis	(pCi/g) ^{1/}	(pCi/g) ^{2/}	(pCi/g) ^{2/}			
<u>MS004</u>							
Ac-228	Gamma Spectroscopy	0.3 U ^{3/}	0.4	0.8			
Bi-212	Gamma Spectroscopy	0.6 U	0.9	1.8			
Bi-214	Gamma Spectroscopy	1.2	0.4	0.7			
Co-60	Gamma Spectroscopy	0.04 U	0.1	0.3			
Cs-137	Gamma Spectroscopy	0.07 U	0.1	0.2			
Gross Alpha	Gross Alpha/Beta	40.5	9.5	6.6			
Gross Beta 4/	Gross Alpha/Beta	840	86	5			
K-40	Gamma Spectroscopy	2.2 U	1.5	3.4			
Pb-212	Gamma Spectroscopy	0.1 U	0.2	0.4			
Pb-214	Gamma Spectroscopy	1.0	0.4	0.4			
Ra-226	Gamma Spectroscopy	1.2	0.4	0.7			
Ra-228	Gamma Spectroscopy	0.3 U	0.4	0.8			
Th-232	Gamma Spectroscopy	0.3 U	0.4	0.8			
Th-234	Gamma Spectroscopy	0.7 U	2.3	4.0			
T1-208	Gamma Spectroscopy	0.03 U	0.1	0.2			
U-235	Gamma Spectroscopy	-1.0 U	1.4	2.4			
U-238	Gamma Spectroscopy	0.7 U	2.3	4.0			
<u>MS004A</u>							
Ac-228	Gamma Spectroscopy	0.2 U	0.5	1.0			
Bi-212	Gamma Spectroscopy	0.02 U	1.0	1.8			
Bi-214	Gamma Spectroscopy	0.5 U	0.3	0.6			
Co-60	Gamma Spectroscopy	-0.04 U	0.1	0.3			
Cs-137	Gamma Spectroscopy	-0.02 U	0.1	0.2			
Gross Alpha	Gross Alpha/Beta	41.8	8.2	3.8			
Gross Beta	Gross Alpha/Beta	481	49	5			
K-40	Gamma Spectroscopy	0.6 U	1.3	2.9			
Pb-212	Gamma Spectroscopy	0.02 U	0.2	0.3			
Pb-214	Gamma Spectroscopy	0.9	0.3	0.4			
Ra-226	Gamma Spectroscopy	0.5 U	0.3	0.6			
Ra-228	Gamma Spectroscopy	0.2 U	0.5	1.0			
Sr-90	Isotopic Beta	199	20	0.7			
Th-228	Isotopic Alpha	0.19	0.1	0.08			
Th-230	Isotopic Alpha	0.23	0.1	0.06			
Th-232	Isotopic Alpha	0.11	0.09	0.09			
Th-232	Gamma Spectroscopy	0.2 U	0.5	1.0			
Th-234	Gamma Spectroscopy	-1.0 U	2.8	4.9			
T1-208	Gamma Spectroscopy	-0.01 U	0.1	0.2			
U-234	Isotopic Alpha	0.43	0.13	0.06			
U-235	Isotopic Alpha	-0.009 U	0.03	0.07			
U-235	Gamma Spectroscopy	1.0 U	1.5	2.8			
U-238	Isotopic Alpha	0.33	0.12	0.03			
U-238	Gamma Spectroscopy	-1.0 U	2.8	4.9			

 $^{1/}$ pCi/g = picocuries per gram.

 $^{2/}$ Uncertainty and MDL as reported by laboratory. MDL = method detection limit.

 $^{3\prime}$ U = analyte was considered non-detected if the result was less than the MDL.

^{4/}Results in bold and italics are considered to be above background.
Radionuclide	Maximum Soil Concentration (pCi/g)
Cs-137	1.22
Nb-94	0.019
Ra-226	2.03
U-232	3.86
U-234	2.74
U-238	1.71

Table 2. TR-6 Maximum Radionuclide Soil Concentrations.

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Radionuclide	Maximum Soil Concentration (pCi/g)	Maximum Debris Concentration (pCi/g)
Cs-137	1.6	
Nb-94	8.9	
Ra-226	3,040	
Pu-242		19.7
Po-210		3,520
Th-229		30.6
Th-230		0.74
U-232	3.91	26.2
U-234	6.4	0.8
U-235	0.13	0.13
U-238	6.7	0.81

Table 4. Soil DCGLs for Unrestricted (Residential) Use.

TR-5 Dose-To-Source- Ratio (DSR)TR-5 (25)Nuclide(mrem/yr per pCi/g)(n		TR-5 DCGL (25 mrem) (pCi/g)	TR-6 Dose-To- Source Ratio (DSR) (mrem/yr per pCi/g)	TR-6 DCGL (25 mrem) (pCi/g)
Carbon-14	1.43E-02	1,753	1.21E-02	2,070
Cesium-137	7.62E-01	33	7.55E-01	33
Niobium-94	2.07E+00	12	2.06E+00	12
Lead-210	9.25E-01	27	8.38E-01	30
Plutonium-242	1.07E-01	234	9.84E-02	254
Radium-226	3.39E+00	7.4	3.26E+00	7.7
Strontium-90	5.29E-01	47	4.80E-01	52
Thorium-229	5.71E-01	44	5.58E-01	45
Thorium-230	8.07E-01	31	7.74E-01	32
Thorium-232	4.04E+00	6.2	3.95E+00	6.3
Uranium-232	1.75E+00	14	1.73E+00	14
Uranium-234	1.98E-02	1,261	1.85E-02	1,353
Uranium-235	1.96E-01	128	1.94E-01	129
Uranium-238	5.12E-02	488	4.98E-02	502

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	TR-5 Dose-To-Source-	TR-5 DCGL	TR-6 Dose-To-	TR-6 DCGL	
Nuclide	(mrem/yr per pCi/g)	(pCi/g)	(mrem/yr per pCi/g)	(pCi/g)	
Carbon-14	1.50E-06	6.68E+07	1.40E-06	71,479,628	
Cesium-137	5.82E-01	172	5.79E-01	173	
Niobium-94	1.65E+00	61	1.64E+00	61	
Lead-210	3.14E-02	3,188	2.86E-02	3,499	
Plutonium-242	1-242 2.33E-02 4,284 2.19E-02		4,564		
Radium-226	dium-226 1.83E+00 55 1.82		1.82E+00	55	
Strontium-90	5.02E-03	19,916	4.94E-03	20,239	
Thorium-229	3.50E-01	285	3.47E-01	288	
Thorium-230	5.00E-01	200	4.97E-01	201	
Thorium-232	2.62E+00	38	2.60E+00	38	
Uranium-232	1.39E+00	72	1.38E+00	73	
Uranium-234	4.25E-03	23,552	4.10E-03	24,414	
Uranium-235	1.46E-01	687	1.45E-01	691	
Uranium-238	3.00E-02	3,329	2.98E-02	3,358	

Table 5. Soil DCGLs for Restricted (Industrial) Use.

General Response	Remedial				
Action No Action	None	None	Not effective. The No Action alternative does not address risk/hazard or reduce the toxicity, mobility, or volume of contamination through treatment. However, it is retained for consideration in the alternatives assembly to measure the effectiveness of the other alternatives.	Implementability Evaluation Not Applicable - No Implementation	No Cost
Land Use Controls	Institutional Controls	Governmental Controls	Effective as they do not require negotiation, drafting, or recording of parcel-by-parcel proprietary controls. Governmental controls remain effective if they are not repealed and are enforced. Examples include zoning; building codes; groundwater use regulations; commercial fishing bans or limits. DOD possesses the authority to enforce ICs on their property.	DPG can specify site uses.	Negligible cost.
		Proprietary Controls	Effective when restrictions on activities are intended to be long-term or permanent between a property owner and second party. Requires the transfer of property to be enforceable. Examples include restricted-use easements and restrictive covenants which can prohibit activities that may compromise the effectiveness of a response action, restrict activities or future resource use, thereby resulting in unacceptable risk to human health or the environment.	Can be implemented without the intervention of any federal, state, or local regulatory authority.	Moderate capital and O&M costs to implement and maintain.
		Enforcement Tools with Institutional Control Components	Effective but typically only binding on the original signatories of the agreement. Enforceable by USEPA under CERCLA and RCRA or by a state. Examples include legal tools such as administrative orders, permits, Federal Facility Agreements which limit certain site activities.	Easier to establish than proprietary controls because USEPA is not dependent on third parties to establish and enforce.	Negligible cost.
		Information Devices	Effective as reduces potential for exposure but does not reduce environmental impacts. Examples include signage, state registries of contaminated sites, tracking systems, and consumption advisories.	DPG can specify site uses.	Negligible cost.
	Engineering Controls	Fencing	Reduces potential for exposure but does not reduce environmental impacts.	High: Requires labor and materials, logistics planning.	Low to Moderate capital and O&M costs to implement and maintain. Maintenance requires recurring inspection and repairs.
Containment	Capping	Clay Liner	Low-Moderate: Minimizes surface water infiltration, controls erosion and surface water runoff, and prevents direct contact of human and ecological receptors. Compared to a GCL, a clay liner may be more permeable, more susceptible to leaks, and can require more maintenance, QA/QC testing, and upkeep over time as a result. Subject to desiccation cracking.	High: Requires labor and materials, logistics planning. Capping material would need regular care and maintenance, must meet compaction standards, and subject to testing. Other locations at site (non-rad) have been capped previously.	Moderate capital costs associated with capping material care and maintenance, requires recurring inspection and repairs. Minimal cost difference compared with GCL after all tests and additional maintenance are considered.
		Geosynthetic clay liner (GCL)	Moderate-High: Effective for minimizing surface water infiltration, controlling erosion and surface water runoff, and prevents direct contact of human and ecological receptors. Considered more effective than a traditional clay liner due to higher impermeability, fewer leaks, and less maintenance required.	High: Requires labor and materials, logistics planning. Capping material would need regular care and maintenance. Other locations at site (non- rad) have been capped previously.	Moderate capital costs associated with capping material care and maintenance, requires recurring inspection and repairs. Minimal cost difference compared with clay liner.

Table 6. Evaluation of General Re	sponse Actions. Remedial	l Technologies, and Proces	s Options.
	sponse i lettons, itemedia	i reennologies, and rivees	5 options

	Retained?	Considerations
	Yes. Required by NCP and USEPA guidance as a baseline for comparison to other options.	
	Yes. Considered in conjunction with other technologies.	
	No. Government facility.	
	Yes: Considered in conjunction with other technologies.	
	Yes: Considered in conjunction with other technologies.	
	Yes: Considered in conjunction with other technologies.	
1	No. Not as effective as GCL and higher cost may be associated with more frequent maintenance, testing, and repairs. For same containment option, GCL is likely more reliable.	
1	Yes: Considered in conjunction with institutional controls. More reliable than a clay liner.	

Table 6. (continued).

General							
Response	Remedial	Due sons Outien	Effectiveness Evolvetion	Investore to bility Furtherstion	Deleting Cost Freehootien	Data: ad9	Considerations
Action 1	Technology	Process Option	Effectiveness Evaluation	Implementability Evaluation	Kelative Cost Evaluation	Ketained:	Considerations
Excavation and	Excavation, Disposal,	Confirmation Soil	High: Physically removes contaminated soil & debris,	High: Easy to implement and commonly	Moderate to High cost	Yes. Removes soil and restores	Distance to off-site disposal
Disposal	& Backfilling	Sampling	transports impacted materials off-site, and replaces	used at other sites.	associated with excavation,	the excavated area with clean	facility; Compliance with
			with clean backfill soil from an on-site source. After		disposal and backfill, soll	soll.	Federal transportation
		Magnetometer or other	remediation is complete, direct exposure to		survey and community		healyfill source on site
		geophysical survey	notential of human health/environmental risks from		sampning.		backini source on-site.
			direct contact incidental ingestion or inhalation of				
			radionuclide soils. Confirmation soil sampling and a				
		Clean soil backfill from	magnetometer (or FIDI ER/GM) survey would confirm				
		an on-site source	all radiological material and trench debris had been				
			removed				
	Excavation Sorting	Confirmation Soil	High: Physically removes the contaminated soil and	Low to High: Easy to implement the	High cost associated with	Yes Removes contaminated	Distance to off-site disposal
	Screening, &	Sampling	debris from the trench, sorts and screens the excavated	excavation, may be difficult to implement	mobilization and demobilization	media and restores the	facility: Compliance with
	Disposal		material on-site to remove contaminated soil and	sorting and screening given the high cost	of sorting and screening	excavated area with original	Federal transportation
	1		debris (i.e., metal tubes), transports impacted material	associated with these process options.	technology.	fill material.	regulations; Cost of
		Sorting & Screening of	to an off-site disposal facility, and returns clean non-	1 1			transporting sorting and
		Contaminated Soil &	radiologically impacted soil to the trench. After				screening technologies to
		Debris	remediation is complete, direct exposure to				the site.
			risks/hazards are eliminated. Would reduce the				
			potential of human health/environmental risks from				
		Detum alaan aail ta	direct contact with tubes. On-site sorting and screening				
		trongh	of soil and debris would be performed to remove				
		uenen	material that is radiologically-impacted. Confirmation				
			soil sampling and a magnetometer (or FIDLER/GM)				
			survey would confirm all radiological material and				
			trench debris above screening limits had been				
			removed.				
Treatment	In-Situ Soil	Cementitious	Moderate-High: Solidification and stabilization of	Moderate to high: Soil stabilization using	Moderate cost associated with	Yes. Once the cement grout	Would need to incorporate
	Treatment	Solidification and	impacted soils and debris eliminates leaching and	cement grout is a commonly used	high-pressure injections and	has solidified, the mobility of	both QC testing (pilot test)
		Stabilization	migration of radionuclides from the soil and is	technique to treat low-level radiological	equipment needs.	radionuclides in soil has been	prior to injection operations
			effective for treating constituents that cannot be	waste.		reduced. Considered in	and geotechnical testing
			degraded into inert forms. Contaminant exposure is			conjunction with institutional	during and after injections.
			reduced through the injection of Portland cement of			controis.	
			has been shown to reduce water infiltration and				
			exposure rate				
			exposure rate.				

Notes: Shading indicates that the remedial technology and/or process option will not be retained for further evaluation.

Evolution Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Evaluation Criteria	No Action	Land Use Controls	Capping and LUCs	Excavation, Disposal, & Backfilling	Excavation, Sorting, Screening, & Disposal	Soil Stabilization
Threshold Criteria						
Overall Protection of Human Health and the Environment	Does not provide overall protection to human health or the environment. Does not reduce or control potential radiological exposure to soil or debris. Impacted materials would not be removed, reduced, or controlled.	A low level of protection to human health is provided by reducing the potential for radiological exposure in soil and debris. However, radiologically-impacted materials are not eliminated or reduced, and the impact on the environment remains the same.	Capping of TR-5 and TR-6 would provide protection to human health and the environment by providing a physical barrier capable of eliminating direct contact to or exposure by current and future receptors from radiologically- impacted soil.	Excavation of radiologically- impacted soil and debris in trenches TR-5 and TR-6 provides protection to human health and the environment by preventing direct contact to or external exposure from contaminated soil and radiological debris.	Excavation of radiologically-impacted (above screening limits) soil and debris in trenches TR-5 and TR-6 provides protection to human health and the environment by preventing direct contact to or external exposure from contaminated soil and radiological debris.	Pressure-injecting grout into TR-5 and TR-6 would provide protection to human health and the environment by limiting direct contact to or exposure by current and future receptors from radiologically-impacted waste.
Compliance with ARARs	ARARs are not met with the No Action alternative, as no remedy would be implemented.	The chemical-specific ARARs for Restricted (Industrial) (10 CFR 20.1403) use is met. Planning will be required to comply with all additional chemical-, location-, and action-specific ARARs.	The chemical-specific ARARs for Restricted (Industrial) (10 CFR 20.1403) use is met. Planning will be required to comply with all additional chemical-, location-, and action-specific ARARs.	The chemical-specific ARARs for Unrestricted (Residential) (10 CFR 20.1402) use is met. Planning will be required to comply with additional chemical-, location-, and action-specific ARARs.	The chemical-specific ARARs for Unrestricted (Residential) (10 CFR 20.1402) use is met. Planning will be required to comply with all additional chemical-, location-, and action-specific ARARs.	The chemical-specific ARAR for Restricted (Industrial) (10 CFR 20.1403) use is met. Planning will be required to comply with all additional chemical-, location-, and action-specific ARARs.
Balancing Criteria						
Long-Term Effectiveness and Permanence	The No Action alternative is not effective or permanent for reducing radiological COCs over time, aside from natural radioactive decay. Potential exposure risks associated with radiological COCs would remain with no controls or long- term management plan.	Alternative 2 provides a low level of long-term effectiveness and permanence through the use of LUCs. Radiologically-impacted materials would remain in the trenches and the risk of human receptor exposure through potentially complete pathways would remain indefinitely.	Alternative 3 would achieve long- term effectiveness and permanence through a GCL cap at TR-5 and TR- 6, combined with LUCs. Capping material would require routine maintenance and inspection by a work crew.	Alternative 4 would achieve long- term effectiveness and permanence through the physical removal of radiologically-impacted soil and debris from TR-5 and TR-6.	Alternative 5 would achieve long-term effectiveness and permanence through the physical removal of radiologically- impacted soil and debris (above screening limits) from TR-5 and TR-6.	Alternative 6 would achieve long- term effectiveness and permanence through cement grouting of soil and debris at TR-5 and TR-6. LUCs would also be implemented. Integrity of the grout would require periodic maintenance and inspection by a work crew.
Reduction of Mobility, Toxicity, Volume, or Mass	The No Action alternative does not employ any treatment that would reduce the toxicity, mobility, volume or mass of impacted material. Natural attenuation processes may reduce radiological COCs over time, but no monitoring will be performed.	Alternative 2 does not provide a reduction in toxicity, mobility, volume, or mass, and radiological COCs would remain in soil and debris.	Alternative 3 would permanently reduce the mobility of radiological COCs in soil through erosion and surface water control. However, the toxicity, volume, and mass of radiological COCs in soil would not be reduced.	Alternative 4 would permanently reduce the toxicity, mobility, volume, and mass of radiological COCs via the physical removal of impacted soil and debris.	Alternative 5 would permanently reduce the toxicity, mobility, volume, and mass of radiological COCs via the physical removal of impacted soil and debris (above screening limits).	Alternative 6 would permanently reduce the mobility of radiological COCs in soil and debris through erosion and surface water control. However, the toxicity, volume, and mass of radiological COCs in soil would not be reduced.
Short-Term Effectiveness	No activities would be implemented that would present potential short- term exposure risks to human health or the environment.	Would result in minimal exposure risks to industrial workers or other human receptors via institutional controls.	Implementation of GCL caps, combined with LUCs, would result in an immediate reduction in potential exposure to site industrial workers.	Implementation of Alternative 4 would be immediately effective upon excavation of impacted soil and debris, but removal activities may result in minimal exposure risks to the construction/industrial workers. Controls will be put in place.	Implementation of Alternative 5 would be immediately effective upon excavation of impacted materials, but removal activities may result in minimal exposure risks to the construction /industrial workers. Controls will be put in place.	Implementation of soil stabilization, combined with LUCs, would result in an immediate reduction in potential exposure to site industrial workers.
Implementability	Alternative 1 is implementable, in that no action would be taken.	Alternative 2 is considered technically feasible, and services and materials should be readily available. Requires administrative planning.	Installation of GCL caps and LUCs is technically feasible, and services and materials for both should be readily available. Requires administrative planning and design of GCL cap.	Alternative 4 is technically implementable via standard excavation practices and technology. Excavation activities should not interfere with ongoing operations at DPG.	Alternative 5 is technically implementable via standard excavation practices and technology. Excavation activities should not interfere with ongoing operations at DPG. Implementing the technology used for sorting and screening of soil and debris on-site may not be feasible given that UU/UE is achievable with Alternative 4 at a lower cost.	Alternative 6 is technically feasible, and services and materials for high- pressure injection of cement grout should be available. Testing, including pilot test, and geotechnical testing would be required, as well as administrative planning.
Cost	No Cost	\$167,000	\$383,000	\$593,000	\$1,439,000	\$487,000

Table 7. Alternatives Summary and Evaluation Comparison.

Modifying Criteria	
State Acceptance	This criterion evaluates the technical and administrative issues and concerns the State of Utah may have regarding each of the alternatives. This criterion will be addressed in the D
-	and Proposed Plan have been received.
Community Acceptance	This criterion evaluates the issues and concerns the public may have regarding each of the alternatives. As with State Acceptance, this criterion will be addressed in the Decision D
	Proposed Plan have been received.

 $\frac{\text{Notes:}}{\text{RACER} \ensuremath{\mathbb{R}}} \text{ software utilized to develop the cost estimates.}$

All costs are estimated to an accuracy of +50 percent to -30 percent (per the USEPA Guide to Developing and Documenting Cost Estimates During the Feasibility Study, dated July 2000).

Decision Document once comments on the Feasibility Study

Document once comments on the Feasibility Study and

Table 8. Cost Analysis of Remedial Alternatives.

Alternatives	Assumptions	Inputs	Total Cost	Capital Costs	Total O&M and Periodic Costs	Present Worth Value
Timeframe: 30 years*						
Alternative 1 - No Action	No Action	None	\$0	\$0	\$0	\$0
Alternative 2 - Land Use Controls	Administrative LUC (Site use controls, Remedial Design, LUCIP, Long-Term Stewardship Plan, LUCIP meetings), Signs, Inspections; Engineering Controls (Fencing around both trenches individually or both trenches as one)	 Remedial Design (medium complexity) LUCIP Plan (medium complexity) LTS Plan (medium complexity) LUCIP meetings 4 signs Annual Inspections 	\$167,000	\$146,000	\$19,000	\$161,000
Alternative 3 - Containment of TR-5 and TR-6 and LUCs	Capping (RCRA Hazardous Waste GCL), Administrative LUC (Site use controls, Remedial Design, LUCIP, Long-Term Stewardship Plan, LUCIP meetings), Signs, Inspections; Engineering Controls (Fencing around both trenches individually or both trenches as one)	RCRA C cap (2) Protective cover minimum of 3 ft cap design 120 ft × 70 ft (8,400 ft ² for TR-5 and TR-6) 40-mil HDPE geomembrane 36-inch protective cover Safety Level D (PPE)	\$383,000	\$ 156,000	\$116,000	\$383,000
Alternative 4 - Excavate, Off-Site Disposal, and Backfill with Clean Soil	Excavate both TR-5 and TR-6, Temporary containment for excavated materials, Confirmation soil sampling/radiological survey, Backfill with certified clean material, Restore surface vegetation, Disposal at ES-Clive disposal facility, No associated O&M or periodic costs	Documentation, planning, and meetings Excavate a total of 1,000 CY from both trenches Excavate to a depth of 7 ft bgs Trucked to ES-Clive for disposal (approx. 80 miles) Backfill with certified clean material	\$593,000	\$593,000	\$0	\$593,000
Alternative 5 - Excavate, Sort, Screen, and Off-Site Disposal	Excavate both TR-5 and TR-6, Temporary containment for excavated materials, Mobilization and Demobilization equipment, On-site radiological screening, Confirmation soil sampling/radiological survey, Backfill with certified clean material, Restore surface vegetation, Disposal at ES-Clive disposal facility, No associated O&M or periodic costs	Documentation, planning, and meetings Mobilization and demobilization of soil screening technology Excavate a total of 1,000 CY from both trenches Excavate to a depth of 7 ft bgs Sort and Screen 1,000 CY of material Assume 20% containment Trucked to ES-Clive for disposal (approx. 80 miles)	\$1,439,000	\$1,439,000	\$0	\$1,439,000
Alternative 6 – Soil Stabilization	High-pressure injection of grout into both TR-5 and TR-6, Pilot test and geotechnical testing, Administrative LUC (Site use controls, LUCIP, Long-Term Stewardship Plan, LUCIP meetings), Signs, Inspections; Engineering Controls (Fencing around both trenches individually or both trenches as one)	Cement grout injected under pressure across surface area of 1,782 ft ² Injected to a depth of 10 ft bgs Injection radius of influence 6 ft in diameter Pilot test and geotechnical testing	\$487,000	\$454,000	\$29,000	\$481,000

Notes: Periodic and O&M costs are estimated over 30 years. Total cost represents the rounded present worth value considering a discount rate of 1.5% for 30 years. Expected accuracy range of -30 percent to +50 percent. Costs are rounded to nearest \$1,000 per EPA guidance. *All costs incurred in Year 1 and Year 2 for Alternatives 4 and 5.

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Appendix A

Characterization Report (included on CD) This page intentionally left blank

Final Characterization Report Area 2 of SWMU-11 Dugway Proving Ground, Dugway, Utah



Prepared for: U.S. Army Environmental Command

> Prepared by: North Wind Services, LLC

February 2020 Rev. 0 (This page intentionally left blank)

RPT-020121-001 Rev. 0

Final Characterization Report Area 2 of SWMU 11

Dugway Proving Ground Dugway, Utah

February 2020

Prepared for:

U.S. Army Environmental Command 2455 Reynolds Road JBSA Fort Sam Houston, Texas 78234

Prepared by:

North Wind Services, LLC. 1425 Higham Street Idaho Falls, Idaho 83402 (This page intentionally left blank)

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APPENDICES

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69		ACRONYMS AND ABBREVIATIONS
70	ALARA	as low as reasonably achievable
71	bgs	below ground surface
72	CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
73	CFR	Code of Federal Regulations
74	COC	contaminant of concern
75	COPC	contaminant of potential concern
76	cpm	counts per minute
77	CSM	conceptual site model
78	CY	cubic yards
79	DCF	dose conversion factor
80	DCGL	Derived Concentration Guideline Level
81	DCGL _{EMC}	Derived Concentration Guideline Level Elevated Measurement Comparison
82	DoD	Department of Defense
83	DPG	Dugway Proving Ground
84	DSR	dose-to-source ratio
85	DWMRC	Utah Division of Waste Management and Radiation Control
86	EPA	United States Environmental Protection Agency
87	FIDLER	Field Instrument for the Detection of Low Energy Radiation
88	FS	Feasibility Study
89	ft	feet
90	ft ²	square feet
91	GM	Geiger Mueller
92	GPR	ground penetrating radar
93	HSA	Historical Site Assessment
94	LTM	long-term maintenance
95	LUC	land use control
96	m^2	square meters

97	MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
98	mg/kg	milligrams per kilogram
99	mg/L	milligrams per liter
100	MoU	Memorandum of Understanding
101	mR/hr	milliroentgen per hour
102	mrem/yr	millirem per year
103	MS	metal sample
104	MW	monitoring well
105	NaI	sodium iodide
106	North Wind	North Wind Services, LLC
107	NRC	U.S. Nuclear Regulatory Commission
108	PCB	polychlorinated biphenyl
109	pCi/g	picocuries per gram
110	PDF	parameter distribution function
111	RCRA	Resource Conservation and Recovery Act
112	RFI	RCRA Facility Investigation
113	RI	Remedial Investigation
114	SB	soil boring
115	SOR	sum of ratios
116	SS	soil sample
117	SVOC	semi-volatile organic compound
118	SWMU	Solid Waste Management Unit
119	TCLP	Toxicity characteristic leaching procedure
120	TDS	total dissolved solids
121	TR	trench
122	VOC	volatile organic compound
123	µR/hr	microroentgen per hour

124 **1. INTRODUCTION**

125 North Wind Services, LLC (North Wind) has prepared this Characterization Report for Area 2 of Solid

126 Waste Management Unit (SWMU) 11 at Dugway Proving Ground (DPG). DPG is located in Tooele

127 County, Utah, and currently serves as the Army's designated major range test facility for chemical and

biological defense. This Characterization Report was developed for the U.S. Army Environmental

Command under Contract No. W9124J-18-D-0007, Delivery Order W9124J18F0088.

130 **1.1 Scope of Work**

131 Area 2 of SWMU 11 is a radiological disposal area of concern that records indicate has never been

132 licensed by the U.S. Nuclear Regulatory Commission (NRC). During 2016, the Department of Defense

133 (DoD) and the NRC finalized a memorandum of understanding (MoU) for the coordination of response

134 actions for DoD sites containing radioactive material (NRC-DoD MoU, 2016). Pursuant to the MoU, the 135 remaining investigation and remediation activities at Area 2 of SWMU 11 are being addressed under the

remaining investigation and remediation activities at Area 2 of SWMU 11 are being addressed u
 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

137 This Characterization Report (1) summarizes the site conditions and prior investigations at Area 2 of

137 This characterization Report (1) summarizes the site conditions and prior investigations at Area 2 of 138 SWMU 11; (2) reviews the existing data set to ensure it is adequate and useable to support the planned

Feasibility Study (FS); and (3) develops Derived Concentration Guideline Levels (DCGLs) for soil in

trenches TR-5 and TR-6 at Area 2 of SWMU 11 consistent with 10 Code of Federal Regulations (CFR)

141 Part 20, Subpart E, as referenced in the 2016 MoU (NRC-DoD MoU, 2016).

142 **2. SITE BACKGROUND INFORMATION**

143 **2.1 Physical Description**

144 DPG covers approximately 840,000 acres in Tooele County in western Utah. DPG is bordered to the

145 northeast by the Cedar Mountains and to the north-northwest by Wendover Air Force Range. SWMU-11,

also known as DPG-011 and the East Granite Holding Area, is located in the remote southwest portion of

147 DPG and lies within a small canyon on the east side of Granite Mountain (Figure 1). SWMU 11 is

148 divided into two distinct areas: Area 1 and Area 2. Area 1 of SWMU 11 consists of three closed trenches

149 (TR-1, TR-2, and TR-3) running roughly east-west along the north side of the canyon and a fourth

backfilled trench (TR-4) running north-south. Area 1 of SWMU-11 was previously evaluated and closed

under Resource Conservation and Recovery Act (RCRA) and corrective action requirements of the Utah
 Division of Waste Management and Radiation Control (DWMRC). Area 2 (0.86 acres) of SWMU 11 is

the radiological disposal area and consists of two trenches (TR-5 and TR-6) and the area adjacent to the

153 the radiological disposal area and consists of two trenches (TK-5) and TK-6) and the area adjactive 154 trenches. Area 2 previously contained a CONEX container; however, it was determined to be

radiologically clear and was removed in 2017 (Marsh, 2017). Figure 2 shows the Area 2 boundary and

156 trench locations. Available evidence indicates that radiological materials were stored in the CONEX

157 container and disposed in trenches TR-5 and TR-6 as early as the mid-1950s, although specific records

regarding materials disposed at Area 2 of SWMU 11 are limited.

159 **2.2 Environmental and Site Characteristics**

160 **2.2.1 Geology**

161 SWMU-11 is located at the mouth of a small, northeast-trending colluvial valley along the eastern side of

- 162 Granite Mountain. The general topography at SWMU-11 is gently sloping down to the east, with an
- average elevation of 4,375 feet (ft) above mean sea level. The valley is flanked to the south by a small

- 164 ridge of granite that extends from the main Granite Mountain area, and to the north and west by granite
- 165 outcroppings characteristic of Granite Mountain. To the east, the valley is open to the broad expanse of
- 166 the Dugway Basin. Granite Mountain is an isolated, north-south trending mountain block approximately
- 167 8 miles long by 6 miles wide. The southern two-thirds of the mountain are dominated by dark colored
- 168 gneiss and gneissic granite with a thin sliver of schists and phyllites at the extreme southern end. 169 The northern one-third of the mountain is made up of intrusive leuco-granitic rocks that form a
- 170 gradational contact with the gneissic granite to the south. Quaternary-aged lacustrine, alluvium, and
- 171 colluvium deposits are present along the flanks of Granite Mountain, including the small valley where
- 172 SWMU-11 is located. Away from the mountain, the surrounding basin floor consists of aeolian sand and
- 173 silt deposits and Quaternary-aged playa and lacustrine sediments associated with deposits of ancient Lake
- 174 Bonneville and older pluvial lakes (Parsons, 2009).

175 2.2.2 Hydrogeology

- 176 Groundwater in the area of SWMU-11 is part of the Dugway Valley aquifer system. Groundwater in this
- region is generally characterized by high total dissolved solids (TDS) and very flat hydraulic gradients.
- 178 However, the flanks of Granite Mountain, including the SWMU-11 site, constitute a local recharge zone
- 179 for basin groundwater. In these localized zones, groundwater is deeper and of higher quality than
- 180 groundwater beneath the basin floor. As groundwater flows from the local recharge area toward the basin
- 181 floor, it becomes increasingly laden with dissolved mineral constituents, and the quality of groundwater is
- 182 greatly diminished. Depth to groundwater near the eastern boundary of SWMU-11 is approximately 61 ft
- below ground surface (bgs) based on water-level measurements from MW-01. An attempt to install a
- 184 second groundwater well in the western portion of SWMU-11 near TR-5 did not reach saturated 185 conditions but rather encountered competent granite bedrock from 72.5 ft bgs to the terminal drilling
- depth of 90 ft bgs. Groundwater flow at SWMU-11 is likely to the east or northeast, based on the local
- 187 topographic gradient present at the site (Parsons, 2009).
- 188 Due to the overall low quality of groundwater in the western DPG region, there have been no potable
- 189 water resources developed in the Granite Mountain area. A non-potable water supply well is located
- 190 6 miles west-northwest of SWMU-11 and is reportedly "very salty" and provides water only for hand
- 191 washing and toilet flushing purposes at the U.S. Air Force Strategic Training Range Complex west of
- 192 Granite Mountain. Another non-potable water well, located approximately 4 miles northwest of
- 193 SWMU-11, is used only for dust suppression. Based on the laboratory TDS measurement of 1,770
- milligrams per liter (mg/L) from the groundwater samples collected at SWMU-11 (well MW-01), the
- local groundwater would be Utah Class 2 drinking water quality groundwater (Parsons, 2009).

2.3 Summary of Prior Site Investigations

- 197 The 1996 Phase I Investigation at SWMU 11 (Parsons, 1996) only addressed Area 1 and did not include
- any activities in Area 2. The investigation of Area 2 began in 2005 during the Phase II RCRA Facility
- 199 Investigation (RFI) of SWMU-11 (Parsons, 2009). While investigating the known trenches (TR-1 through 200 TR-4) and surrounding area with geophysical and radiological scans, two additional burial trenches on the
- 201 west side of TR-4 were discovered and subsequently designated as TR-5 and TR-6.

202 2.3.1 2005 Phase II Investigation

- 203 During the Phase II investigation (Parsons, 2009), the following activities were completed in Area 2:
- Magnetometer survey;
- Radiological survey using scanning measurements and direct measurements;

- Collection of four surface soil (0 to 0.5 ft bgs) samples from TR-5 (SS40 SS43) and two surface soil samples from TR-6 (SS44 and SS45) for laboratory analysis of metals, gross alpha, gross beta, gamma spectroscopy, and Strontium-90.
- Collection of one material sample from TR-5 (MS4/MS4A metal remnant of drum material) for
 laboratory analysis of metals, gross alpha, gross beta, gamma spectroscopy, isotopic uranium, isotopic
 thorium, and Strontium-90.
- Collection of one material sample from TR-6 (MS2 solidified sand from inside a corroded drum)
 for analysis of metals, volatile organic compounds (VOCs), semivolatile organic compounds
 (SVOCs), and dioxins/furans.
- Excavation of one test pit (EP15) to investigate potentially buried wastes in TR-6. One soil sample
 was collected from the base of the test pit (10 ft bgs) and analyzed for metals, VOCs, SVOCs, and
 dioxins/furans.
- Drilling of one soil boring (SB06) and collection of one subsurface soil sample to characterize
 subsurface soil downgradient of Area 2. The soil sample was analyzed for VOCs, perchlorate, metals,
 gross alpha, gross beta, gamma spectroscopy, and Strontium-90.
- The magnetometer survey identified anomalies in TR-5 and TR-6. Additionally, anomalous radioactivity was measured at both TR-5 and TR-6. The Phase II results identified that TR-6 contained various types of debris, including small metal tubes that had low levels of radioactivity consistent with Cesium-137. Soils surrounding these materials were at background radiation levels; however, in the absence of more conclusive laboratory analysis, the waste in TR-6 was considered unidentified. A localized area of highly elevated radioactivity was present at TR-5. Due to the hazards associated with the area, intrusive activities
- 227 were not completed. Due to the presence of these uncharacterized and unidentified materials in TR-5 and
- 228 TR-6, further investigation of the Area 2 radiological portion of SWMU-11 was recommended.
- 229 Phase II sample locations are documented in Figure 3. Further discussion of the Phase II radiological
- assessment is provided in Section 3.2.1. The Phase II report (Parsons, 2009) did not specifically address
- the non-radiological chemical results from TR-5 and TR-6 samples, which included detections of metals,
- 232 SVOCs, and dioxins/furans.

233 **2.3.2 2014 Investigation**

- In 2014, non-intrusive portions of the Remedial Investigation (RI)/FS Work Plan were completed at Area 2 of SWMU 11 (Cabrera, 2014). This included surficial gross gamma radiological scans and geophysical
- 236 (Schondstedt magnetometer and ground penetrating radar [GPR]) scans across the area (Figure 4).
- 237 TR-5 was delineated by both the geophysical and radiological surveys as a surface area of approximately
- 440 square feet (ft²), with approximately 2 ft of soil cover and extending approximately another 4 ft in
- depth beyond the covering soil. Surface gamma emitting radioactive material was detected at TR-5.
- 240 Visual inspection of the TR-6 area showed some surface trash consisting of metal tubes and possible soil
- 241 piles 1 ft high to 1-1/2 ft high by 8 to 10 ft long. Some metal was detected in these low soil mounds. Buried
- 242 metal is interpreted to be scattered over an area approximately 12 ft by 16 ft. This suggests that trash was
- spread out and then covered with a thin layer of soil. Radar scanning crossed through the area of TR-6;
- however, the radar energy did not penetrate through the salty soil in this location. Therefore, little
- 245 information was gained on TR-6 from the GPR scan.

- 246 The combination of radiological and geophysical investigation results confirmed and delineated the TR-5
- boundaries. There were no indications of surface elevated gross gamma activity on or around TR-6 or
- 248 outside of the TR-5 boundary based on the radiological investigation. Although the TR-6 geophysical
- investigation was hampered by soil conditions, the results indicate a surface area of approximately 12 by
- 250 16 ft of shallow soil mounds covering areas of debris.

251 **2.3.3 2016 Investigation**

- In 2016, intrusive portions of the RI/FS Work Plan were completed at Area 2 of SWMU 11
- 253 (Cabrera, 2016). The following activities were completed:
- Identification of 10 soil borings locations in TR-5 and five soil boring locations in TR-6. Each boring
 location included a surface soil and subsurface soil sample for laboratory analysis of VOCs, SVOCs,
 metals, gamma spectroscopy, isotopic uranium, Strontium 90, Tritium, and Carbon 14.
- One soil sample was collected for toxicity characteristic leaching procedure (TCLP) analysis of
 VOCs, SVOCs, metals, pesticides, herbicides, polychlorinated biphenyls (PCBs), reactive sulfide,
 and reactive cyanide.
- One debris sample was collected for analysis of gamma spectroscopy, isotopic uranium, isotopic
 thorium, isotopic plutonium, isotopic polonium, ²²⁶Ra, and ⁹⁰Sr.
- Soil cores were scanned with a Geiger Mueller (GM) pancake probe.
- Soil boring locations were evaluated with downhole gamma logging using a sodium iodide (NaI) detector.

The 2016 sampling locations are depicted on Figure 5. The 2016 investigation report concluded that there 265 266 is radioactive contamination in TR-5 soil exceeding established screening criteria (Cabrera, 2016). There 267 were no soil results that exceeded screening criteria in Trench TR-6. However, previous test pitting 268 activities in TR-6 have uncovered several drums and debris, some of which contain small amounts of 269 radioactivity. There were no exceedances for any chemical samples (i.e., VOCs, SVOCs, or metals) above 270 the TCLP regulatory limits presented in 40 CFR 261.24. Therefore, the report concluded that it is unlikely 271 that any wastes generated from the excavation of the trenches will result in hazardous or "mixed" waste. 272 Because the Phase II chemical data from TR-5 and TR-6 had not been considered in a similar fashion, North Wind conducted a review of Phase II chemical data and noted the arsenic result of 155 milligrams 273 274 per kilogram (mg/kg) for MS02 (TR-6; solidified sand from inside a drum). Considering the 275 concentration of arsenic in the drum contents, during implementation of a future remedy at Area 2 of 276 SWMU 11, TCLP analysis of the contents of drums within TR-6 may be warranted.

277 3. RADIOLOGICAL CHARACTERIZATION

278 **3.1 Radiological History**

279 In the DPG RCRA Facility Application, SWMU-11 was one of the seven reported radioactive landfills.

280 Historic records regarding radiological materials handling were summarized in the 2009 Phase II RFI

281 (Parsons, 2009). Specific records regarding radiological materials disposed at SWMU-11 are limited. The

East Granite Holding Area (e.g., SWMU-11) is not identified in the available literature as being

associated with the testing of radiological munitions conducted at DPG in the 1950s and 1960s. Historical inspection records indicate that buried wastes in the SWMU-11 area consisted primarily of "contaminated

- rags and papers." Inspection records from the U.S. Atomic Energy Commission indicate that low level
- radioactive waste materials were repackaged for sea disposal in the Able Area. Waste from this activity may have also been disposed at the DPG burial area corresponding to SWMU-11 after the sea disposal
- 288 program was discontinued.
- 289 Radioactive waste materials from laboratory activities in other areas of DPG were stored in a CONEX
- 290 container at SWMU-11 to protect individual storage containers from the elements. Materials stored in the
- 291 CONEX container included Tritium and Carbon-14. In March 1980, contaminated glassware was
- removed from the CONEX by the DPG radiation safety officer and disposed at an offsite location. During
- the 2005 Phase II investigation, no waste remained in the CONEX container (Parsons, 2009). The
- 294 CONEX container was determined to be radiologically clear and was removed in 2017 (Marsh, 2017).
- In June 2000, DPG notified the NRC about SWMU-11. During a limited survey of the area conducted in
- 296 September 2000, NRC personnel were unable to detect any radioactivity significantly above background.
- In March 2001, the NRC stipulated that any required decommissioning activities at SWMU-11 could take
- 298 place under the radioactive materials license currently held by DPG. However, in March 2006, the NRC
- notified DPG that the NRC would evaluate if a new license was necessary to conduct decommissioning
- 300 activities under the current radioactive materials license (for possession of sealed sources associated with 301 an irradiator). During 2016, the DoD and the NRC finalized a MoU for the coordination of response
- an irradiator). During 2016, the DoD and the NRC finalized a MoU for the coordination of response actions for DoD sites with radioactive materials (NRC-DoD MoU, 2016). Pursuant to the MoU, the
- remaining investigation and remediation activities at Area 2 of SWMU 11 are being addressed under
- 304 CERCLA.
- 305 The 2014 Radiological Assessment (Cabrera, 2014) states that based on available historical records for
- activities in the Avery Area (i.e., SWMU-41), Cobalt-60 was considered to be a contaminant of potential
- 307 concern (COPC) at SWMU 11. Available records indicate the Cobalt-60 was used only in sealed sources,
- 308 making it unlikely that any materials contaminated with Cobalt-60 were disposed at SWMU 11. Records
- 309 indicate that all Cobalt-60 sealed sources were moved off-site (i.e., off DPG property) after their use.
- Cobalt-60 has not been detected in any of the investigations at SMWU-11.
- 311 The 2014 report also notes that radium-containing parts and devices are common on military installations.
- 312 It may be present in military items as a result of its luminescent properties; instrument dials, gauges, and
- watches painted with radium containing paint are common. Consequently, it was included as a COPC forSWMU-11.

315 3.2 Radiological Characterization Data Review

316 3.2.1 2005 Phase II Radiological Data

- 317 The Phase II investigation surface scans identified an area of anomalously elevated radiological activity at
- TR-5. As noted in the Phase II report (Parsons, 2009), this area was also conspicuously devoid of
- 319 vegetation and was marked by a slight topographic depression. Gamma exposure rate measurements
- ranged from 420 microroentgen per hour (μ R/hr) at the center of the area to 50 μ R/hr at a distance of 3 ft.
- Background radiation levels (approximately 30 μ R/hr) were observed approximately 6 feet away from
- this point. Additional field measurements taken directly over the area with a Field Instrument for the
 Detection of Low Energy Radiation (FIDLER) (measuring gamma radiation) showed readings up to
- 323 Detection of Low Energy Radiation (FIDLER) (measuring gamma radiation) showed readings up to 324 575,000 counts per minute (cpm). A GM pancake probe (measuring beta radiation) produced readings of
- 325 1,200 cpm. Background radiation levels for these instruments at SWMU-11 were between 25,000 and
- 326 28,000 cpm for the FIDLER and 75 to 125 cpm for the GM Pancake probe. Approximately 4 to 6 inches
- of soil was scraped from the area with a shovel, and the exposure rate over the spot increased to
- approximately 2 milliroentgen per hour (mR/hr) (2,000 μ R/hr) or about five times that observed prior to

- 329 soil removal. The soil over the anomalous area was not radioactive itself but was instead covering buried
- radioactive waste material under the area. The scraped soil was placed back over the area and
- 331 radioactivity returned to the original exposure rate reading of approximately 420 μ R/hr.
- 332 While the field measurements identified elevated activity, the Phase II soil data generally did not. The
- 333 Phase II sampling included six surface soil samples (SS40-SS45) and one subsurface soil sample (SB06)
- collected for laboratory analysis. Aside from a single detection of Strontium-90 (4.4 picocuries per gram
- [pCi/g] in SS42 TR5), all of the reported Phase II radiological soil data results were within twice the
- average background levels.
- 337 The Phase II investigation included sampling of metallic debris from TR-5 (sample MS04/MS04A;
- 338 0.25 ft bgs). This sample had gamma spectroscopic characteristics similar to those of the surface anomaly.
- Based on the analytical results, the metal (MS04/MS04A) was concluded to be a ferrous metal that had been contaminated with Strontium-90. The source, depth, and quantity of material was not determined
- been contaminated with Strontium-90. The source, depth, and quan(Parsons, 2009).
 - 342 Based on the field screening of metal tube debris sample MS03 (TR-6; 7 ft bgs), it was noted that the
 - 343 gamma radiation shared a peak on the gamma spectrum with Cesium-137. Due to uncertainties with
 - respect to the contents of the metallic cylinders, they were not shipped for laboratory analyses.
 - 345 In summary, the Phase II investigation detected an area of anomalously elevated radiation and identified
 - potential radiological contaminants of concern (COCs) (i.e., Strontium-90 at TR-5 and Cesium-137 at
 - TR-6) based on field screening and/or laboratory analytical results. However, aside from a single
 - 348 Strontium-90 result, the limited number of surface soil samples did not show any appreciable radiological
 - 349 impacts.

350 3.2.2 2014 Radiological Data

351 The 2014 investigation (Cabrera, 2014) confirmed the Phase II surface scanning results. No elevated

- surface activity was identified at TR-6. Elevated readings were confirmed in TR-5, with maximum
- activities in the southern half of TR-5 (Figure 4). No laboratory samples were collected during this
 investigation.

355 **3.2.3 2016 Radiological Data**

The 2016 investigation included 15 boring locations (including 10 at TR-5 and five at TR-6). At each location, core scanning and downhole gamma logging were used. In addition, 34 soil samples and one debris sample were collected for confirmatory laboratory analyses (Cabrera, 2016).

Soil core scans exhibited elevated radioactivity (i.e., at least twice the background levels) only at borehole
 locations 14 (0 to 1-ft interval) and 15 (0 to 1-ft and 1 to 2-ft intervals) at TR-5. These two borings are
 located in the southern half of TR-5, which is consistent with prior investigations that identified that area

- 362 as having elevated field screening results.
- 363 Figure 6 depicts a cross-section view of downhole gamma logging data at TR-5. Figure 7 depicts the
- downhole gamma logging data and inferred extent of impact in plan view. Downhole gamma logging
- showed that boreholes 14 and 15 (i.e., the biased locations within Trench TR-5) clearly had elevated
- radioactivity. The majority of the radioactivity appeared to be within the top 3 or 4 ft of material. There
- are also elevated activities found in the intervals below 4 ft bgs. Boreholes 1, 3, 8, and 9 have higher
- readings from 4 to 8 ft bgs. Boreholes 2, 4, and 7 have higher readings from 1 to 5 ft bgs, with boreholes 2 and 4 possibly going deeper. Boreholes 2, 8, and 13 were located on the approximate western edge of

- TR-5. There are also elevated activities found in the intervals below 4 ft bgs; however, these are possibly
- due to "shine" from the higher activity material above or different background radiation levels associated with fill material inside the trench
- 372 with fill material inside the trench.
- 373 Downhole gamma logging showed no indication of elevated radioactivity in TR-6 boreholes 5, 6, 11, and
- 12. All readings at all depths were less than 9,000 cpm. TR-6 Borehole 10 is located within the TR-6
- footprint on the northern end; the highest downhole gamma logging result was 10,504 cpm at the 5 to 6-ft
- 376 interval, and the upper 6 ft of material displayed radioactivity greater than 9,000 cpm. This borehole was 377 located directly next to a known metal anomaly found during the geophysical survey. It is likely that the
- 377 located directly next to a known metal anomaly found during the geophysical survey. It is likely that the 378 slightly elevated readings are associated with the metal anomaly. Previous investigations in this trench
- found metallic debris containing small amounts of low-level radioactivity.
- 380 The 2016 laboratory analytical results generally corroborate the gamma scanning results in that the highest
- detected radionuclide concentrations most frequently occurred at TR-5 boreholes 14 and 15 (which also
- had the most elevated radioactivity during field scans). Bismuth-214, Lead-214, Radium-226, and
- 383 Strontium-90 concentrations at SB15 were one to two orders of magnitude greater than concentrations in
- other borings. Section 3.4 presents a summary of analytical data for Area 2 of SWMU-11.
- 385 The six highest concentrations of Cesium-137 occurred in TR-6, which supports the Phase II field
- screening result that identified possible Cesium-137 in debris sample MS03. A summary of 2016 soil data
- is provided in Table 1. Table 2 provides 2016 debris sample results.

388 3.3 Data Usability

- 389 The identification of COCs from the 2005 and 2014 investigations was based on radiological field
- 390 screening (2005 and 2014), limited laboratory analytical data (2005 only), and the limited historical
- 391 records of materials disposed at Area 2 SWMU 11. A discussion of the data quality for these prior events
- is presented in the prior investigation reports (Parsons, 2009 and Cabrera, 2014). During the 2016
- investigation, substantially more laboratory analytical data were collected. The 2016 soil was analyzed by
- ALS Laboratories for gamma spectroscopy (Method 713R13), Strontium-90 (724R11), Tritium and
- Carbon-14 (704R10), and isotopic Uranium, Thorium, and Plutonium (714R12). All detected isotopes
- 396 were requested to be reported for the gamma spectroscopy analyses.
- 397 The 2005 radiological laboratory results (and detection limits) were reviewed and compared to the 2016
- data set and the screening criteria discussed in Section 3.4. With the exception of Strontium-90, the 2005
- 399laboratory results were less than the 2016 results. The Strontium-90 result (199 pCi/g from sample
- 400 MS-04) was greater than the 2016 detection (19.2 pCi/g). However, this does not create any uncertainty
- 401 because Strontium-90 was retained as a COC (Section 3.4). Cobalt-60 was not reported in the 2016 data
- set but was reported as "non-detect" in the 2005 data. The reported detection limit of Cobalt-60
 (0.19 pCi/g) was less than the dose compliance concentration based on 10 mrem/yr for a residential land
- 405 (0.19 pCl/g) was less than the dose compliance concentration based on 10 mrem/yr for a residential lan 404 use scenario (1.6 pCi/g); thus, it is not a COC. The 2016 laboratory analytical data are concluded to be
- 405 conservative and complete, and it is unlikely that potentially significant radionuclides have been missed.
- 406 An evaluation of 2016 field and laboratory data quality was included in the Final Report for Area 2
- 407 SWMU 11 (Cabrera, 2016). The discussion notes that false positive results are potential for Cobalt-56,
- 408 Manganese-54, Europium-54, Niobium-94, and Antimony-125. Given the uncertainty with respect to the
- 409 materials that were disposed in Area 2 SWMU 11, no detected analytes were eliminated from the data set,
- 410 even if they were potential analytical artifacts. This approach is conservative and ensures no potentially
- 411 significant radionuclides are omitted.
- The 2016 data set was, therefore, concluded to be of sufficient quality to use for its intended purpose of defining the nature and extent of radiological impacts at TR-5 and TR-6.

414 **3.4 Radiological Contaminants of Concern**

415 The radiological data described above were used to define COCs. Tables 1 and 2 present the radiological

416 constituents detected in the 2016 soil and debris samples, respectively. As a conservative screening to

417 identify COCs, the maximum detection in soil or debris was compared to the dose compliance

418 concentration protective of a residential land use scenario and dose limit of 10 millirem per year

419 (mrem/yr). The dose compliance concentrations were obtained using the U.S. Environmental Protection

- 420 Agency (EPA) web-based calculator (<u>https://epa-dccs.ornl.gov/cgi-bin/dose_search</u>).
- 421 The soil (Table 1) and debris (Table 2) concentrations were also compared to twice the average site-
- 422 specific background concentrations. Site specific background data were established in the Phase II report
- 423 (Parsons, 2009) and background comparisons and frequency of detection screenings were used during the
- 424 RI process at SWMU 11. Background comparisons are frequently used as a screening protocol for
- inorganics and naturally occurring radionuclides in CERCLA evaluations. There are various approaches
 for conducting background comparisons, including simple techniques as well as more advanced statistical

420 for conducing background comparisons, including simple techniques as well as more advanced statistic 427 techniques. Comparing the maximum detected site concentrations to twice the average background is a

427 techniques. Comparing the maximum detected site concentrations to twice the average background is a 428 simple approach that is commonly used. Ultimately, Postassium-40 was the only constituent removed

420 simple approach that is commonly used. Ultimately, Postassium-40 was the only constituent removed 429 from the final list of COCs (combined list from soil and debris) for Area 2 SWMU 11 based on the

430 comparison to background.

The following constituents had concentrations less than the screening criteria and/or background but were
 nonetheless included as COCs:

- Cesium-137 was included as a COC due to the Phase II investigation field screening results that suggested it may be present inside the cylindrical tubes identified as debris in TR-6.
- Lead-210 was included as a COC due to the unexpected Polonium-210 detection in the 2016 debris
 sample, and the likelihood that it was present in secular equilibrium (see the laboratory explanation in
 Appendix A).
- Carbon 14 was included as a COC due to the maximum detection in SB15 co-located with the area of maximum activity, and given the fact that Carbon-14 contaminated materials (e.g., glassware in the former CONEX box) have historically been documented at SWMU-11.
- 441 The following four constituents were included as COCs because they had non-detect results that exceeded442 dose compliance concentrations:
- Cobalt-56 had a non-detect result of 126 pCi/g as compared to a dose compliance concentration of 1.22 pCi/g).
- Iron-59 had a non-detect result of 5.2 pCi/g as compared to a dose compliance concentration of 3.8 pCi/g).
- Niobium-95 had a non-detect result of 7.9 pCi/g as compared to a dose compliance concentration of 6.4 pCi/g).
- Thorium-227 had a result of 8.1 pCi/g as compared to a dose compliance concentration of 1.3 pCi/g).
- 450 These non-detect results are not included on Table 1 but can rather be found in the Final Phase II RI
- 451 Report (Cabrera, 2016). The elevated reporting limits for these constituents all occurred at location SB15,
- 452 which is the location of the highest field scanning results as well as the greatest radionuclide
- 453 concentrations based on the laboratory data.

- 454 The final list of COCs includes: Actimum-228, Bismuth-212, Bismuth-214, Carbon-14, Cesium-137,
- 455 Cobalt-56, Iron-59, Lead-210, Lead-212, Lead-214, Niobium-94, Niobium-95, Protactinium-234m,
- 456 Plutonium-242, Polonium-210, Radium-226, Strontium-90, Thorium-229, Thorium-230, Thorium-232,
- 457 Thorium-234, Thorium-227, Uranium-232, Uranium-234, Uranium-235, and Uranium-238. Several of
- these constituents (e.g., Bismuth-214, Protactinium-234, etc.) are short-lived daughter products that have
- half-lives of minutes, hours, or days. The determination of derived guideline concentration levels will be
- 460 based on parent radionuclide plus daughters.

461 **3.5 COC Extent and Characteristics**

462 The extent and characteristics of radiological COCs are distinct between the two trenches at Area 2 of463 SWMU-11.

464 **3.5.1 TR-6 COC Extent and Characteristics**

465 At TR-6, there were no field scanning results to indicate any substantially elevated radioactivity at land 466 surface. Also, the radiological laboratory soil results were all uniform, with no particular sample greatly exceeding others. The only indication of radiological concern at TR-6 is the potential presence of 467 468 Cesium-137 that was initially identified in the Phase II debris sample MS03. Small metal tubes were 469 identified at a depth of 7 ft bgs during the excavation of test pit EP15 (Figure 3). When scanned in the 470 field, several of the metal tubes had gamma peaks consistent with Cesium-137. Although 2016 471 concentrations of Cesium-137 in soil were less than the dose compliance concentration screening levels (Table 1), the 2016 soil samples from SB-05, SB-10, SB-11, and SB-12 did have Cesium-137 472 473 concentrations that were greater than those documented in TR-5. Lastly, the 2016 downhole gamma 474 logging results at SB-10 had slightly elevated responses. This borehole was located directly next to a 475 known metal anomaly found during the geophysical survey (Figure 5). It is possible that the slightly 476 elevated readings could be associated with the metal anomaly. Based on the available data, the metallic 477 debris in TR-6 may contain Cesium-137. Such debris may occur throughout TR-6, and particularly in the 478 areas where geophysical anomalies were identified (Figure 5). The waste volume was estimated by 479 Cabrera (2016) as 165 cubic yards (CY) with approximate dimensions of 40 ft long by 20 ft wide by 6 ft 480 deep. However, the approximate dimensions of 40 ft long by 20 ft wide by 6 ft deep for TR-6 results in 481 178 CY. Therefore, for the DCGL development, the larger volume of 178 CY was used since this results 482 in conservative (i.e., lower) DCGLs.

483 **3.5.2 TR-5 COC Extent and Characteristics**

- 484 At TR-5, the SB-15 laboratory results generally corroborate the downhole gamma logging results
- 485 presented in Section 3.2.3. Maximum concentrations of Radium-226 (3,040 pCi/g), Strontium-90
- 486 (19.2 pCi/g), Bismuth-214 (2,100 pCi/g), Niobium-94 (8.9 pCi/g), and Lead-214 (2,200 pCi/g) were
- reported at the 0 to 1-ft interval of location SB-15. As an example of COC extent, Radium-226 results
- 488 exceeding two times average background levels (2.6 pCi/g) occurred at locations SB-13 (4.84 pCi/g, 0 to
- 489 1 ft), SB-02 (3.77 pCi/g, 5 to 6 ft), SB-14 (7.26 pCi/g, 0 to 1 ft), SB-15 (3,040 pCi/g, 0 to 1 ft and
- 490 40.7 pCi/g, 5 to 6 ft), and SB-04 (14.5 pCi/g, 5-6 ft).
- 491 In three locations having elevated surface gamma readings, the radiological screening was conducted after
- 492 excavating down 1 ft to determine if the contamination was caused by a discrete source, or if it was
- 493 distributed throughout the area of elevated gamma activity. A discrete source for the contamination was
- 494 not found; therefore, the radiological contamination was concluded to be relatively homogeneous
- 495 (within the areas of elevated gamma results) (Cabrera, 2016).

- 496 In summary, the field screening and laboratory results indicate that COCs at TR-5 are elevated within the
- trench, with detections exceeding background in surface and subsurface soil and the highest
- 498 concentrations in the surface intervals at SB-15 and SB-14. The estimated excavation waste volume for
- 499 TR-5 was 194 CY (Cabrera, 2016), assuming approximate dimensions of 46 ft long by 17 ft wide by up to
- 500 7 ft deep. However, the approximate dimensions of 46 ft long by 17 ft wide by 7 ft deep for TR-5 results
- in 203 CY. Therefore, for the DCGL development, the larger volume of 203 CY was used since this
- 502 results in conservative (i.e., lower) DCGLs.

5034. DETERMINATION OF DERIVED CONCENTRATION GUIDELINE504LEVELS (DCGLs)

505 The purpose of this section is to describe the methods used to calculate site-specific DCGLs for soil in 506 TR-5 and TR-6 at SWMU 11 and to provide the results of the calculations. The dose modeling methods

- 507 and assumptions are described and the results of the DCGL calculations provided. This includes the 508 selection of the critical group, exposure scenario, conceptual site model (CSM) for soil, RESRAD
- 509 ONSITE input parameters, and analysis results.

510 **4.1** Applicable or Relevant and Appropriate Requirements

511 Applicable or relevant and appropriate requirements for radiological COCs in soil at the site are identified

512 in 10 CFR 20.1402 (Radiological Criteria for Unrestricted Use) and 10 CFR 20.1403 (Criteria for License

513 Termination Under Restricted Conditions). Provisions of both 10 CFR 20.1402 and 10 CFR 20.1403

require that the annual dose to an average member of the critical group not exceed 25 mrem/yr, and that

515 the residual radioactivity be reduced to levels that are as low as reasonably achievable (ALARA).

516 However, unlike 10 CFR 20.1402, 10 CFR 20.1403 allows this dose limit to be achieved through the use

517 of engineering and land use controls (LUCs), with the added requirement that the annual dose does not

518 exceed 100 mrem/yr should those institutional controls fail or if they are no longer in effect.

519 4.2 Modeled Radiological Contaminants of Concern

520 Several COCs listed in Section 3.4 are short-lived radionuclides that would not persist in the waste

521 without a long-lived parent. These radionuclides include Co56, Fe-59, and Nb-95. These radionuclides

- 522 were not modeled for DCGLs since they would not be present in the waste due to decay.
- 523 Additional short-lived radionuclides are listed as COCs in Section 3.4 that have long-lived parent

radionuclides. These radionuclides include Ac-228, Bi-212- Bi-214, Pb-212, Pb-214, Pa-234m, Po-210,

525 Th-234, and Th-227. These short-lived radionuclides were included in the decay chains of the long-lived

526 parent radionuclides that were identified as a COC.

527 Based on the radiological COCs presented in Section 3.4, the following radionuclides and radionuclide 528 decay chains (i.e., identified as +D) were modeled for the DCGLs:

- C-14,
- 530 Cs-137 + D (i.e., Ba-137m),
- 531 Nb-94,
- 532 Pb-210 + D (i.e., Bi-210, Po-210),
- 533 Pu-242 + D (i.e. U-238 decay series),

- Ra-226 + D (i.e., Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210 and Po-210),
- 535 Sr-90 + D (i.e., Y-90),
- Th-229 + D (i.e., Ra-225, Ac-225, Fr-221, At-217, Bi-213, Tl-209, Pb-209 and Po-213),
- 537 Th-230 + D (i.e., Ra-226 decay series),
- 538 Th-232 + D (i.e., Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 and Po-212),
- U-232 + D (i.e., Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 and Po-212),
- U-234 + D (i.e., Th-230 decay series),
- U-235 + D (i.e., Th-231, Pa-231, Ac-227, Fr-223, Ra-223, Rn-219, Po-215, Pb-211, Bi-211, Tl-207, Po-211 and Th-227), and
- U-238 + D (i.e., Th-234, Pa-234m, Pa-234 and U-234 decay series).

545 The dose conversion factors (DCFs) in the isotope library used in RESRAD ONSITE (Kamboj et al.,

546 2018) assumes that progeny isotopes with radioactive half-lives less than 180 days are in secular

equilibrium with their parent (i.e., an isotope with a half-life greater than 180 days). Consequently, the

- dose contributions from the short-lived progeny of the long-lived radium nuclides are automatically
- included in the calculations. In addition, RESRAD ONSITE automatically calculates the ingrowth
- 550 concentrations of the longer-lived progeny in the decay chains and accounts for the dose contributions 551 from these nuclides.
- 552 The entire list of COCs were used at both TR-5 and TR-6 to develop DCGLs, regardless of where the
- 553 COC was identified. The unity rule, also termed the sum-of-ratios (SOR) (as provided in Section 4.5),
- would be used for any sample obtained from either TR-5 or TR-6 for those radionuclides detected in the

sample. Therefore, determining DCGLs for all COCs identified at both trenches ensures that if a

radionuclide were detected at TR-6 that was not previously found during characterization activities, a

557 DCGL would be available. However, the only difference in the DCGLs for TR-5 and TR-6 is the volume

of soil brought to the surface, and thus, the areal extent of the resulting 0.15-meter (6-inch) soil layer.

4.3 Conceptual Site Model

560 This section presents the CSM for the DCGL development. This includes a description of the critical 561 groups, exposure pathways, and conceptual model of the source.

562 4.3.1 Critical Groups

563 In general, DCGLs were developed for two dose scenarios: (1) residential (i.e., unrestricted), which

- requires no LUCs (or long-term maintenance [LTM]) based on 25 mrem/yr; and (2) industrial
- 565 (i.e., restricted release), which occurs after loss of LUCs or LTM based on 100 mrem/yr. The RESRAD
- 566 ONSITE computer model (Kamboj et al., 2018) was used for all modeling for the development of the
- 567 DCGLs.
- 568 The Resident Farmer was selected as the critical group for DCGL development for unrestricted release
- under 10 CFR 20.1402. A Resident Farmer critical group results in more conservative DCGLs (i.e., lower
- 570 concentrations) than an industrial use critical group due primarily to the increased dose from the
- 571 consumption of food grown onsite and occupancy time considerations.

- 572 An Industrial Worker was selected as the critical group for DCGL development for restricted release
- under 10 CFR 20.1403. The Industrial Worker is considered to be representative of the likely future useof the Dugway site.

575 **4.3.2 Exposure Pathways**

576 A Resident Farmer was assumed to move onto the site, build a home, and establish a farm for raising 577 crops and livestock for a 30-year period. The Resident Farmer scenario assumes exposure to residual 578 radioactivity through several exposure pathways, including:

- Direct radiation;
- Inhalation of re-suspended dust;
- 581 Direct ingestion of soil;
- Ingestion of food from crops grown in contaminated soil and irrigated with site water;
- Ingestion of water from a well contaminated by water percolated through the contaminated area; and
- Ingestion of meat and milk from livestock raised using on-site well water and feed grown within the contaminated soil that has been irrigated with site water.
- 586 An Industrial Worker was assumed to work at the site 8 hours per day, 250 days per year for 30 years.
- 587 The Industrial Worker was assumed to work outdoors at the site for 7 hours per day and is indoors for
- 1 hour per day. The Industrial Worker scenario assumes exposure to residual radioactivity through several
 exposure pathways, including:
- 590 Direct radiation;
- Inhalation of re-suspended dust;
- 592 Direct ingestion of soil; and
- Ingestion of water from a well contaminated by water percolated through the contaminated area.
- The Radon exposure pathway is not included in the dose assessment for the Resident Farmer or Industrial
 Worker scenarios, which is consistent with the guidance provided in NUREG-1757, Volume 2, Appendix
 J.

597 **4.3.3 Conceptual Model of the Source**

598 The Resident Farmer and Industrial Worker scenarios assume that the entire volume of contaminated soil

in a trench is exhumed and spread over the ground surface, resulting in a 6-inch contaminated soil layer

600 (Figure 8). This is a conservative assumption based on Appendix J of NUREG-1757, where a dose

assessment strategy for buried waste is provided. The use of this strategy simplifies the analysis and

602 provides a conservative estimate of the radionuclide DCGLs.

603 **4.4 RESRAD Onsite Input Parameters**

The RESRAD ONSITE computer code was run using deterministic parameters. The parameters were selected by first categorizing the parameters as behavioral, metabolic, or physical in accordance with the recommendations in NUREG/CR-6697. Consistent with the guidance in NUREG-1757, Section I.6.4.2,

- 607 the behavioral and metabolic parameters were assigned the mean of the parameter distribution function
- 608 (PDF) recommended in NUREG-5512, Volume 3, when available. The metabolic and behavioral
- 609 parameters are listed in Table 3.
- 610 The preferred method for the selection of physical parameters was the use of site-specific values
- 611 determined by measurement or analysis or from literature values based on the site soil type. If site-
- 612 specific information was not available, a parameter priority ranking method was used to guide the
- 613 parameter selection process.
- 614 The method for selecting the physical parameters that were not site-specific depended on their relative
- 615 effect on the calculated dose. NUREG/CR-6697, Attachment B, provides a detailed analysis of the
- 616 physical parameters. The result was a ranking of the parameters as Priority 1, Priority 2, or Priority 3.
- 617 Priority 1 parameters generally have the greatest effect on dose, while Priority 3 parameters generally
- 618 have the least. The parameter priority rankings are provided in NUREG/CR-6697, Attachment B, Table
- 619 4-2, and are also noted in this report in Appendix B, Tables B-1 and B-2, for the parameter values
- 620 selected for the Resident Farmer and Industrial Worker scenarios.
- 621 Priority 3 parameters that were not site-specific were assigned the RESRAD ONSITE deterministic
- default values. Priority 1 and 2 parameters that were not site-specific were assigned values based on the
- 623 median or mean value from the PDFs provided in NUREG/CR-6697, Attachment C.
- 624 The selected RESRAD ONSITE parameter values for the Resident Farmer and the Industrial Worker are 625 provided in Appendix B, Tables B-1 and B-2, respectively.

626 **4.5 Soil DCGL Development**

- 627 An initial unit concentration of 1 pCi/g for each radiological COC was used in conjunction with the
- 628 RESRAD ONSITE input parameters provided in Appendix B. The peak dose to the average member of
- the critical group, from each radiological COC, was calculated over a 1,000-year period and was defined
- as the peak dose-to-source ratio (DSR). The DSR, in units of mrem/yr per pCi/g, was then divided into
- 631 the dose limit of interest (25 mrem or 100 mrem annual dose) to determine the site-specific DCGL for
- each radiological COC.
- Each radionuclide-specific DCGL represents the concentration of residual activity, above background,
- that would result in the dose limit of interest to the average member of the critical group (i.e., 25 or 100
- 635 mrem annual dose). When multiple radionuclides are present, compliance is addressed using the unity
- 636 rule.

The unity rule, also termed the SOR, is used when multiple radionuclides exhibit unknown or variable
 relative concentrations throughout the site. The unity rule is considered the default approach for assessing
 multiple radionuclides in soil against their respective DCGLs.

640 The unity rule, or SOR, is:

$$SOR = \left(\frac{C_1}{DCGL_1}\right) + \left(\frac{C_2}{DCGL_2}\right) + \dots + \left(\frac{C_n}{DCGL_n}\right)$$

- 642 where:
- 643 C = radionuclide concentration (pCi/g)
- 644

641

= derived concentration guideline level (pCi/g).

DCGL

645 **4.6 Groundwater Pathway Evaluation**

646 Groundwater in the area of SWMU-11 is part of the Dugway Valley aquifer system. Groundwater in this

region is generally characterized by high TDS and flat hydraulic gradients. However, the flanks of

648 Granite Mountain (including the SWMU-11 site) constitute a local recharge zone for basin groundwater.

649 In these localized zones, groundwater is deeper and of higher quality than groundwater beneath the basin

- 650 floor. As groundwater flows from the local recharge area toward the basin floor, it becomes increasingly 651 laden with dissolved mineral constituents, and the quality of groundwater is greatly diminished.
- addition with dissolved initiate constituents, and the quanty of groundwatch is greatly unitinisticu.
- Parsons (2009) proposed installing two groundwater monitoring wells (MW01 and MW02). MW02 was
- located in the western portion of the site closer to Granite Mountain. Several attempts to drill MW02 were
- unsuccessful due to bedrock conditions encountered that prevented advancement of the MW02 boring to
- 655 groundwater. As such, the boring, which began as "MW02," was completed as "SB06," and a soil
- 656 (rather than a groundwater) sample was collected at this location (Parsons, 2009).
- 657 Depth to groundwater at SWMU-11 is approximately 61 ft bgs based on water-level measurements from
- 658 MW01. Groundwater flow at SWMU-11 is likely to the east or northeast, based largely on the local
- topographic gradient present at the site (Parsons, 2009).
- 660 Due to the overall low quality of groundwater in the western DPG region, there have been no potable
- water resources developed in the Granite Mountain area. Water well WW32, located 6 miles west-
- northwest of SWMU-11, is reportedly "very salty" and provides water only for hand washing and toilet
- 663 flushing purposes at the U.S. Air Force Strategic Training Range Complex, which is located west of
- 664 Granite Mountain. Water well WW10, located approximately 4 miles northwest of SWMU-11, is
- 665 currently used for dust suppression only. Historical information available from the Utah Division of
- 666 Water Rights indicates that water from well WW10 was not fit for human consumption and was used only 667 for municipal purposes (e.g., boiler feed, fire suppression, and decontamination) at the Granite Peak
- 668 Installation-2 (GPI-2; SWMU-4) facility. Groundwater quality at SWMU-11 is Class II (drinking water
- quality) per Utah Administrative Code R317-6-3 (DWQ, 2019), based on the laboratory TDS
- 670 measurement of 1,770 mg/L from the groundwater sample collected from MW01 (Parsons, 2009).
- The groundwater pathway was evaluated in the Residential Farmer scenario for SWMU 11, Area 2.
- 672 Conservative parameter values were used for the groundwater pathway, basing the parameter values for
- the unsaturated and saturated zones on the typical properties of sand. Table 4 provides the RESRAD
- ONSITE results for the travel time of radionuclides to the aquifer at SWMU-11, Area 2, based on sand
- 675 sorption coefficients, as presented in Appendix B.
- 676 The travel time for all the radiological COCs of interest are greater than the 1,000-year model period.
- 677 Therefore, the radiological COCs will not migrate to the groundwater during the assessment period.
- In addition, evidence from the attempt to install MW02 near SWMU 11, Area 2, indicates that the
- development of a water well in this area of the site may not be possible. Therefore, the groundwater
- 680 pathway is not a significant contributor to the receptor doses at SWMU 11, Area 2.

681 4.7 Site-Specific DCGLs

The soil DCGLs for the Resident Farmer at TR-5 and TR-6 are provided in Table 5. The soil DCGLs for
 the Industrial Worker at TR-5 and TR-6 are provided in Table 6.

684 4.8 DCGL_{EMC} (Area Factors)

685 Area factors were developed in accordance with the Multi-Agency Radiation Survey and Site

686 Investigation Manual (MARSSIM) to evaluate the dose from small areas of elevated activity. The area

factors were developed for each CSM by adjusting the size of the contaminated zone and dividing the

resulting DCGL for the smaller areas of activity (DCGL_{EMC}) by the applicable site DCGL. Area factors for the excavation scenario were calculated for contaminated zone sizes of 1, 5, 10, and 50 square meters

- (m^2) . Larger areas of interest are not necessary since the trench areas are 72.65 m² for TR-5 and 74.32 m²
- 691 for TR-6.
- 692 The elevated trench activity for the DCGL development was assumed to be excavated intact and brought
- to the surface, with the only modification to "flatten" the material from the trench depths of 2.13 meters
- 694 (TR-5) and 1.83 meters (TR-6) to the excavation scenario surface soil depth of 0.15 meter. Therefore, the
- area factors are constrained to a soil averaging depth of 0.15 meter (6 inches). An example use of these area factors would be to evaluate small areas of elevated radionuclides at the bottom of the excavations to
- determine if additional remediation is necessary. Thus, the constraint that the area factors apply only to an
- averaging depth of 0.15 meter (6 inches) is reasonable based on the typical sample depth of 0.15 meter
- 609 (6 inches) for radiological samples in soil. The area factors for the Residential Farmer scenario are
- provided in Tables 7 and 8 for TR-5 and TR-6, respectively. The area factors for the Industrial Worker are
- 701 provided in Tables 9 and 10 for TR-5 and TR-6, respectively.
- The DCGLs for elevated measurement comparison (DCGL_{EMC}) are obtained by multiplying the
- applicable DCGL by the area factor that corresponds to the actual area of the elevated concentrations of
- interest. For example, assume that an elevated area (5 m^2) of Ra-226 activity is located at the bottom of
- the TR-5 excavation after remediation. The unrestricted release DCGL for Ra-226 is 7.4 pCi/g (see Table
- 5); therefore, the DCGL_{EMC} for Ra-226 in a 5-m² area for the unrestricted release would be the DCGL times the 5 m² area for the unrestricted release would be the DCGL
- times the 5-m² area factor, which is 5.1 (see Table 7), resulting in a DCGL_{EMC} of 37.7 pCi/g. Therefore, if the 5-m² area at the bottom of the excavation, averaged over a depth of 0.15 meter (6 inches), is equal to
- or less than 37.7 pCi/g, no further remediation of this elevated area is required (assuming no other
- 710 radionuclides were present in the sample).

711 **4.9 DCGL Sensitivity and Uncertainty Analysis**

- 712 DCGL sensitivity and uncertainty analyses were also conducted on the RESRAD models for the Resident
- Farmer and Industrial Worker scenarios. The details of the sensitivity and uncertainty analysis are
- 714 provided in Appendix C. A brief summary of the methods and results is provided below.
- A parameter sensitivity analysis was conducted for the Resident Farmer and Industrial Worker scenarios
- 716 for Ra-226 at TR-5. Ra-226 was chosen for the sensitivity and uncertainty analysis since it is widely 717 distributed through out TR 5. Similar parameter constituities and uncertainties would be supported for the
- distributed throughout TR-5. Similar parameter sensitivities and uncertainties would be expected for the
- other COCs for which DCGLs were developed. The parameters considered in the sensitivity analyses
 were based on those provided in NUREG/CR-6697. The values for each parameter of interest were varied
- were based on those provided in NUREG/CR-6697. The values for each parameter of intereand evaluated at a minimum, midpoint and maximum value in RESRAD-ONSITE.
- The following parameters were found to have the highest sensitivities in the Resident Farmer scenario:
- 722 1. Sorption coefficient (K_d) of the contaminated zone;
- 723 2. Density of the contaminated zone;
- 724 3. Runoff coefficient;

- 725 4. External gamma shielding factor;
- 726 5. Fruit, vegetable, and grain consumption rate;
- 727 6. Soil ingestion;
- 728 7. Depth of soil mixing layer;
- 729 8. Depth of roots;
- 730 9. Indoor time fraction; and
- 731 10. Evapotranspiration coefficient.
- 732 The following parameters were found to have the highest sensitivities in the Industrial Worker scenario:
- 733 1. Sorption coefficient (K_d) of the contaminated zone,
- 734 2. Density of the contaminated zone,
- 735 3. Runoff coefficient,
- 736 4. External gamma shielding factor,
- 737 5. Soil ingestion,
- 738 6. Depth of soil mixing layer, and
- 739 7. Evapotranspiration coefficient.

740 Uncertainty analyses were conducted for the Resident Farmer and Industrial Worker scenarios for the

parameters found to be the most sensitive based on the sensitivity analyses. Two uncertainty analyses

were run for each of the Resident Farmer and Industrial Worker scenario consisting of (1) parameter

uncertainty based on the lower quartile (25%) and upper quartile (75%) of the sensitive parameters based

on the RESRAD-ONSITE parameter distributions provided in NUREG/CR-6697, and (2) parameter
 uncertainty based on sampling of the full RESRAD-ONSITE parameter distributions provided in

- 746 NUREG/CR-6697.
- The DCGL results of the uncertainty analyses are summarized in Table 11. The base case DCGL model
 results based on the deterministic runs are also shown to provide a comparison to the uncertainty results.
- 749 The full parameter distribution uncertainty results, based on the peak-of-the mean dose distribution, are in

agreement with the deterministic base case model results. The peak-of-the-mean DCGLs are considered

to be appropriate to compare with the deterministic DCGLs because NRC indicates that when using

- probabilistic dose modeling, the peak-of-the-mean dose distribution should be used for demonstrating
- compliance with its License Termination Rule in 10 CFR 20, Subpart E (NUREG-1757).
- 754 The quantile parameter value uncertainty analyses produced DCGLs that were less than both the
- deterministic based case model DCGLs and the full parameter distribution uncertainty DCGLs. However,
- the use of the lower and upper quartiles for the parameter values is considered overly conservative
- considering the conservatism already built into the conceptual models for the Resident Farmer and
- 758 Industrial Worker scenarios.
- As noted in Section 4.3.3, the Resident Farmer and Industrial Worker scenarios assume that the entire
- volume of contaminated soil in a trench is exhumed and spread over the ground surface, resulting in a
- 6-inch contaminated soil layer. This is a conservative assumption based on Appendix J of NUREG-1757,
- where a dose assessment strategy for buried waste is provided. The use of this strategy simplifies the
- analysis and provides a conservative estimate of the radionuclide DCGLs.
- 764 In addition, several additional conservatisms were incorporated into the Resident Farmer and Industrial
- 765 Worker scenarios. These conservatisms include the assumption that a Resident Farmer would actually be
- able to develop a well in the area to provide water for farming (see Section 4.6). The Industrial Worker
- 767 scenario also includes the conservative assumption that the worker would be present at this remote site $\frac{1}{2}$
- with no facilities for 8 hours per day, 250 days per year for 30 years (see Section 4.3.2).
- 769 After consideration of the results of the probabilistic uncertainty analyses, and the conservatism built into
- the deterministic base case scenarios, it was determined that it is appropriate to use the deterministic base
- case DCGLs, supported by the peak-of-the-mean DCGLs, for the TR-5 and TR-6 DCGLs.

772 5. MARSSIM CLASSIFICATIONS

773 MARSSIM requires that areas be initially classified as impacted or non-impacted based on the results of

the Historical Site Assessment (HSA). Non-impacted areas have no reasonable potential for residual

contamination and require no further evidence to demonstrate compliance with the release criterion. In

accordance with previous reports for SWMU 11, Area 2, TR-5, TR-6, and their buffer areas are
 considered impacted (Parsons 2009; Cabrera 2014; Cabrera 2016). Radioactive materials have been found

- considered impacted (Parsons 2009; Cabrera 2014; Cabrera 2016). Radioactive materials have been found
 at both TR-5 and TR-6. In addition, the buffer areas are considered to be potentially impacted due to their
 proximity to the trenches.
- 780 Impacted areas are areas that have the potential for containing contaminated material. They can be781 subdivided into the following three classes:
- Class 1 Areas: Areas that have, or had prior to remediation, a potential for radioactive contamination (based on site operating history) or known contamination (based on previous radiological surveys).
 Note that areas containing contamination in excess of the DCGL prior to remediation should be classified as Class 1 areas.
- Class 2 Areas: These areas have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are not expected to exceed the DCGL. To justify changing an area's classification from Class 1 to Class 2, the existing data (from the HSA, scoping surveys, or characterization surveys) should provide a high degree of confidence that no individual measurement would exceed the DCGL.
- Class 3 Areas: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the DCGL, based on site operating history and previous radiological surveys. Examples of areas that might be classified as Class 3 include buffer zones around Class 1 or Class 2 areas, and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification.

At SWMU 11, Area 2, TR-5 is classified as a Class 1 area. The radionuclides (i.e., specifically Ra-226) in
 TR-5 would likely exceed the DCGLs based on the reported soil concentrations provided in Cabrera
 (2016).

TR-6 is also classified as a Class 1 area. The radionuclides at TR-6 are not likely to exceed the DCGLs;
 however, as noted in MARSSIM:

To justify changing an area's classification from Class 1 to Class 2, the existing data
(from the HSA, scoping surveys, or characterization surveys) should provide a high
degree of confidence that no individual measurement would exceed the DCGL.

According to Parsons (2009), TR-6 contains various types of debris, including small metal tubes that have low levels of radioactivity consistent with Cesium-137 but which remain unidentified in the absence of conclusive radiological analyses. Although the waste in TR-6 was visually inspected and screened during test pit excavation, this material could not be fully identified. MS03, the representative sample of a metal tube, was not sent off-site for laboratory analysis due to uncertainties regarding the use and associated hazards of this item. Therefore, since analytical results are not available to conclusively identify the metal tubes, the waste in TR-6 is considered unidentified. Based on this uncertainty, TR-6 is classified as a

- 811 Class 1 area.
- 812 As discussed in Section 2.3.2, Cabrera (2014) conducted a gross gamma surface investigation throughout
- 813 Area 2 of SWMU 11. The radiological survey area results were combined and overlaid with the TR-5 and
- 814 TR-6 geophysical results (Figure 4) to confirm the trench boundaries delineated by both investigations.
- 815 There were no indications of surface radioactive material on or around TR-6 or outside of the TR-5
- boundary based on this radiological investigation. Therefore, the buffer areas of TR-5 and TR-6 are
- 817 classified as Class 3 areas.

818 6. SURVEY UNIT IDENTIFICATION

A survey unit is a physical area consisting of land areas of specified size and shape for which a separate decision will be made as to whether that area exceeds the release criterion.

821 To facilitate survey design and ensure that the number of survey data points for a specific site are

822 relatively uniformly distributed among areas of similar contamination potential, the site is divided into

823 survey units that share a common history (or other characteristics), or are naturally distinguishable from

other portions of the site. A site may be divided into survey units at any time before the final status

- survey. For example, HSA or scoping survey results may provide sufficient justification for partitioning
 the site into Class 1, 2, or 3 areas. However, according to the MARSSIM (NUREG-1575), dividing the
- site into survey units is critical only for the final status survey. Scoping, characterization, and remedial
- action support surveys may be performed without dividing the site into survey units.
- 829 Survey units should be limited in size based on classification, exposure pathway modeling assumptions,
- and site-specific conditions. The MARSSIM (NUREG-1575) suggested areas for survey units are provided in Table 12
- 831 provided in Table 12.
- 832 The areal extent of TR-5, TR-6, and the buffer areas are within the recommended MARSSIM survey unit
- areas provided in Table 12. Therefore, TR-5 and TR-6 are each considered a survey unit. The buffer areas
- 834 surrounding TR-5 and TR-6 are also considered a survey unit. The survey units are shown in Figure 9 and 835 the areas of the survey unit are provided in Table 12.
- 836

837 7. SUMMARY AND CONCLUSIONS

- 838 This Characterization Report summarized the site conditions and prior investigations at Area 2 of SWMU
- 839 11; reviewed the existing data set to ensure it is adequate and useable to support the planned FS; and
- 840 developed DCGLs for soil in TR-5 and TR-6 at Area 2 of SWMU 11.
- 841 The 2016 data set (Cabrera, 2016) was evaluated and concluded to be of sufficient quality to use for its
- 842 intended purpose of defining the nature and extent of radiological impacts at TR-5 and TR-6. Gamma
- 843 surface scans of Area 2 (Cabrera, 2014) also indicated that the buffer areas around the trenches did not
- 844 exhibit elevated activity.
- 845 Site-specific DCGLs for the radionuclide COCs were developed and are reported in Tables 5 for the
 846 Residential Farmer scenario and in Table 6 for the Industrial Worker scenario.
- 847 In addition, area factors have also been generated to account for contaminated soil areas smaller in size
- than the areas used in the model. These area factors for the Residential Farmer scenario are presented in
- 849 Table 7 for TR-5 and in Table 8 for TR-6. The area factors for the Industrial Worker scenario are
- 850 presented in Table 9 for TR-5 and in Table 10 for TR-6.
- 851 A sensitivity and uncertainty analysis was also conducted for the Resident Farmer and Industrial Worker
- 852 scenarios in Section 4.9 and Appendix C. The results of this analysis (Table 11) support the use of the
- deterministic DCGLs presented in Section 4.7 and Tables 5 and 6.
- TR-5 and TR-6 were determined to be Class 1 areas with survey units equal to their full areal extent of
- 94 m^2 and 68 m^2 , respectively. The remainder of SWMU-11, Area 2 is a Class 3 buffer area with a survey unit size of $3,328 \text{ m}^2$.

857 8. REFERENCES

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864	Radiological Criteria for License Termination."
865	Code of Federal Regulations, Title 10, Part 20.1402, "Standards for Protection Against
866	Radiation–Radiological Criteria for Unrestricted Use."
867	Code of Federal Regulations, Title 10, Part 20.1403, "Standards for Protection Against Radiation–
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FIGURES





901 902 From: Cabrera, 2016

903 **Figure 2. Site Layout.**

Characterization Report Area 2 SWMU 11 Dugway, Utah







From: Cabrera, 2014 (Note that the Connex box has subsequently been removed).





From: Cabrera, 2016 (Note that the Connex box has subsequently been removed).





916 917

Figure 6. TR-5 Cross-Sections.



920 921

From: Cabrera, 2016 (Note that the Connex box has subsequently been removed).





924 925 **From: NUREG-1757**

926 Figure 8. Simplified Conceptual Model of Waste Distribution.



928 Figure 9. Classification and Survey Units, Area 2, SWMU-11.

TABLES

Analyte	Units	Frequency of Detection	Range of Detections	Maximum Detection	Arithmetic Average of Detections	Dose Compliance Concentration (DL=10) ¹	Max Detect > DCC? ⁵	2X Average Background ²	Max Detect > 2X Background?	COC?
Actinium-228	pCi/g	33 / 34	1.68 - 3.74	3.74	2.33	1	Yes	3.6	Yes	Yes
Antimony-125	pCi/g	1 / 34	9.8	9.8	9.8	11.2	No	NA		No
Bismuth-212	pCi/g	33 / 34	1.67 - 3.72	3.72	2.52	3.15	Yes	2.4	Yes	Yes
Bismuth-214	pCi/g	34 / 34	1.01 - 2100	2100	64.11	0.2	Yes	2.6	Yes	Yes
Carbon-14	pCi/g	1 / 34	21	21	21	102	No	NA		Yes ³
Cerium-144	pCi/g	1 / 34	-0.032	-0.032	-0.032	69.3	No	NA		No
Cesium-134	pCi/g	8 / 34	0.037 - 0.115	0.115	0.067	2.51	No	NA		No
Cesium-137	pCi/g	19 / 34	0.03 - 1.22	1.22	0.287	5.88	No	2.2	No	Yes ⁴
Cobalt-56	pCi/g	20 / 34	0.095 - 0.224	0.224	0.146	1.22	No	NA		No
Europium-152	pCi/g	9 / 34	0.106 - 0.2	0.2	0.153	4.17	No	NA		No
Europium-155	pCi/g	20 / 34	0.09 - 0.171	0.171	0.121	158	No	NA		No
Lead-212	pCi/g	33 / 34	1.89 - 4.02	4.02	2.56	2.64	Yes	3.6	Yes	Yes
Lead-214	pCi/g	34 / 34	1.15 - 2200	2200	67.32	0.198	Yes	2.6	Yes	Yes
Manganese-54	pCi/g	11 / 34	0.029 - 0.05	0.05	0.039	5.11	No	NA		No
Niobium-94	pCi/g	2 / 34	0.084 - 8.9	8.9	4.49	3.08	Yes	NA		Yes
Potassium-40	pCi/g	33 / 34	16.6 - 32.7	32.7	26.83	2.62	Yes	52.2	No	No
Protactinium-234m	pCi/g	1 / 34	5.4	5.4	5.4	0.143	Yes	NA		Yes
Radium-226	pCi/g	34 / 34	1.16 - 3040	3040	92.97	0.155	Yes	2.6	Yes	Yes
Strontium-90	pCi/g	7 / 34	0.29 - 19.2	19.2	3.68	0.457	Yes	NA		Yes
Thallium-208	pCi/g	33 / 34	0.528 - 1.22	1.22	0.75	1.31	No	1.2	Yes	No
Thorium-234	pCi/g	33 / 34	1.68 - 3.86	3.86	2.63	0.151	Yes	ND	Yes	Yes
Tritium	pCi/g	2 / 34	0.035 - 0.224	0.224	0.13	60.3	No	NA		No

931 Table 1. COC screening for SWMU-11 (Area 2) 2016 soil data.

Table 1. (continued).

Analyte	Units	Frequency of Detection	Range of Detections	Maximum Detection	Arithmetic Average of Detections	Dose Compliance Concentration (DL=10) ¹	Max Detect > DCC? ⁵	2X Average Background ²	Max Detect > 2X Background?	COC?
Uranium-232	pCi/g	34 / 34	2.06 - 3.91	3.91	3.25	0.78	Yes	NA		Yes
Uranium-234	pCi/g	34 / 34	0.9 - 6.4	6.4	1.52	0.151	Yes	NA		Yes
Uranium-235*	pCi/g	3 / 34	0.113 - 0.185	0.185	0.146	0.134	Yes	ND	Yes	Yes
Uranium-235 ⁺	pCi/g	28 / 34	0.016 - 0.35	0.35	0.072	0.134	Yes	ND	Yes	Yes
Uranium-238	pCi/g	34 / 34	0.78 - 6.7	6.7	1.23	0.149	Yes	ND	Yes	Yes

* U-235 results from method 713R13

+ U-235 results from method 714R12

(1) DCC for residential land use scenario (<u>https://epa-dccs.ornl.gov/cgi-bin/dose_search</u>) and adjusted to be protective of 10 mrem/yr dose limit.
 (2) Site background data from Phase II Investigation (Parsons, 2009).

(3) Carbon-14 included as COC due to maximum detection co-located with other COCs and the historic documented presence of C-14 impacted materials at SWMU-11.

(4) Cesium-137 included as a COC due to field screening results that indicate it may be present inside the metal tube debris in TR-6.

(5) DCC is the dose compliance concentration.

Analyte	Units	Detection	Dose Compliance Concentration (DL=10) ¹	Detect > DCC?	2X Average Background ²	Detect > 2X Background?	COC?
Actinium-228	pCi/g	1.23	1	Yes	3.6	No	No
Bismuth-212	pCi/g	1.46	3.15	No	2.4	No	No
Bismuth-214	pCi/g	1.56	0.2	Yes	2.6	No	No
Cesium-137	pCi/g	0.034	5.88	No	2.2	No	No
Cobalt-56	pCi/g	0.164	1.22	No	NA		No
Lead-210	pCi/g						Yes ³
Lead-212	pCi/g	1.16	2.64	No	3.6	No	No
Lead-214	pCi/g	1.57	0.198	Yes	2.6	No	No
Plutonium-242	pCi/g	19.7	0.146	Yes	NA		Yes
Polonium-209	pCi/g	740	744	No	NA		No
Polonium-210	pCi/g	3520	5.04	Yes	NA		Yes
Potassium-40	pCi/g	16.6	2.62	Yes	52.2	No	No
Radium-226	pCi/g	2.23	0.155	Yes	2.6	No	No
Strontium-90	pCi/g	3.7	0.457	Yes	NA		Yes
Thallium-208	pCi/g	0.36	1.31	No	1.2	No	No
Thorium-228	pCi/g	0.84	1.25	No	NA		No
Thorium-229	pCi/g	30.6	1.38	Yes	NA		Yes
Thorium-230	pCi/g	0.74	0.154	Yes	NA		Yes
Thorium-232	pCi/g	0.84	0.367	Yes	NA		Yes
Thorium-234	pCi/g	1.83	0.151	Yes	ND	Yes	Yes
Uranium-232	pCi/g	26.2	0.78	Yes	NA		Yes
Uranium-234	pCi/g	0.8	0.151	Yes	NA		Yes
Uranium-238	pCi/g	0.81	0.149	Yes	ND	Yes	Yes

Table 2. COC screening for SWMU-11 (Area 2) 2016 debris data. 932

(1) DCC for residential land use scenario (<u>https://epa-dccs.ornl.gov/cgi-bin/dose_search</u>) and adjusted to be protective of 10 mrem/yr dose limit.
(2) Site background data from Phase II Investigation (Parsons, 2009).

(3) Lead-210 was included as a COC due to the unexpected Po-210 detection in the 2016 debris sample and likelihood that it was present in secular equilibrium (see lab explanation in Appendix A).

Parameter	Units	Classification
Inhalation rate	m ³ /yr	Metabolic
Fraction of time spent indoors	unit-less	Behavioral
Fraction of time spent outdoors (on-site)	unitless	Behavioral
Fruit, vegetable, and grain consumption	kg/yr	Behavioral
Leafy vegetable consumption	kg/yr	Behavioral
Milk consumption	L/yr	Behavioral
Meat and poultry consumption	kg/yr	Behavioral
Soil ingestion rate	g/yr	Behavioral
Drinking water intake	L/yr	Behavioral

934 Table 3. RESRAD ONSITE metabolic and behavioral parameters.

935

936 **Table 4. Radionuclide travel time to the aquifer.**

Nuclide	Travel Time to Aquifer (yr)
C-14	1,113
Cs-137	60,506
Nb-94	34,589
Pb-210	58,346
Pu-242	118,820
Ra-226	108,020
Sr-90	3,273
Th-229	691,150
Th-230	691,150
Th-232	691,150
U-232	7,593
U-234	7,593
U-235	7,593
U-238	7,593

Nuclide	TR-5 Dose-To-Source-Ratio (DSR) (mrem/yr per pCi/g)	TR-5 DCGL (25 mrem) (pCi/g)	TR-6 Dose-To-Source Ratio (DSR) (mrem/yr per pCi/g)	TR-6 DCGL (25 mrem) (pCi/g)
C-14	1.43E-02	1,753	1.21E-02	2,070
Cs-137	7.62E-01	33	7.55E-01	33
Nb-94	2.07E+00	12	2.06E+00	12
Pb-210	9.25E-01	27	8.38E-01	30
Pu-242	1.07E-01	234	9.84E-02	254
Ra-226	3.39E+00	7.4	3.26E+00	7.7
Sr-90	5.29E-01	47	4.80E-01	52
Th-229	5.71E-01	44	5.58E-01	45
Th-230	8.07E-01	31	7.74E-01	32
Th-232	4.04E+00	6.2	3.95E+00	6.3
U-232	1.75E+00	14	1.73E+00	14
U-234	1.98E-02	1,261	1.85E-02	1,353
U-235	1.96E-01	128	1.94E-01	129
U-238	5.12E-02	488	4.98E-02	502

Table 5. Soil DCGLs for the Resident Farmer Scenario. 938

939 Note: Ingrowth of daughter products is included in the analysis.

Table 6. Soil DCGLs for the Industrial Worker Scenario. 940

Nuclide	TR-5 Dose-To-Source- Ratio (DSR) (mrem/yr per pCi/g)	TR-5 DCGL (100 mrem) (pCi/g)	TR-6 Dose-To-Source- Ratio (DSR) (mrem/yr per pCi/g)	TR-6 DCGL (100 mrem) (pCi/g)
C-14	1.50E-06	6.68E+07	1.40E-06	71,479,628
Cs-137	5.82E-01	172	5.79E-01	173
Nb-94	1.65E+00	61	1.64E+00	61
Pb-210	3.14E-02	3,188	2.86E-02	3,499
Pu-242	2.33E-02	4,284	2.19E-02	4,564
Ra-226	1.83E+00	55	1.82E+00	55
Sr-90	5.02E-03	19,916	4.94E-03	20,239
Th-229	3.50E-01	285	3.47E-01	288
Th-230	5.00E-01	200	4.97E-01	201
Th-232	2.62E+00	38	2.60E+00	38
U-232	1.39E+00	72	1.38E+00	73
U-234	4.25E-03	23,552	4.10E-03	24,414
U-235	1.46E-01	687	1.45E-01	691
U-238	3.00E-02	3,329	2.98E-02	3,358
Note: Ingrowth	of daughter products is included in the	analysis.		

	$\frac{1}{1}$					
Nuclide	1	5	10	50		
C-14	16,478	2,143	831	84		
Cs-137	11	3.5	2.3	1.4		
Nb-94	11	3.4	2.2	1.3		
Pb-210	637	185	101	23		
Pu-242	11	8.7	7.8	5.5		
Ra-226	17	5.1	3.4	1.9		
Sr-90	504	124	69	17		
Th-229	6.5	3.3	2.4	1.6		
Th-230	16	5.5	3.7	2.1		
Th-232	12	4.1	2.8	1.6		
U-232	11	3.6	2.4	1.4		
U-234	6.2	5.1	4.6	3.5		
U-235	9.1	3.2	2.1	1.3		
U-238	8.5	3.8	2.7	1.7		

942 Table 7. TR-5 Area Factors for the Residential Farmer.

943 Note: Ingrowth of daughter products is included in the analysis.

944 **Table 8. TR-6 Area Factors for the Residential Farmer.**

	Elevated Area of Interest (m ²)				
Nuclide	1	5	10	50	
C-14	13,959	1,815	704	71	
Cs-137	11	3.5	2.3	1.4	
Nb-94	11	3.4	2.2	1.3	
Pb-210	512	146	79	17	
Pu-242	10	8.0	7.2	5.0	
Ra-226	16	4.9	3.2	1.9	
Sr-90	457	113	62	16	
Th-229	6.3	3.2	2.3	1.5	
Th-230	16	5.3	3.5	2.0	
Th-232	12	4.0	2.7	1.6	
U-232	11	3.5	2.4	1.4	
U-234	5.8	4.8	4.3	3.3	
U-235	9.0	3.1	2.1	1.3	
U-238	8.3	3.7	2.6	1.6	

945 Note: Ingrowth of daughter products is included in the analysis.

		Elevated Area of Interest (m ²)					
Nuclide	1	5	10	50			
C-14	31	13	8.9	4.5			
Cs-137	11	3.4	2.2	1.3			
Nb-94	11	3.4	2.2	1.3			
Pb-210	77	38	26	11			
Pu-242	5.2	4.3	4.0	3.1			
Ra-226	11	3.5	2.3	1.3			
Sr-90	12	3.8	2.5	1.5			
Th-229	6.8	3.0	2.1	1.4			
Th-230	11	3.5	2.3	1.4			
Th-232	11	3.4	2.3	1.4			
U-232	11	3.5	2.3	1.4			
U-234	3.0	2.5	2.3	1.8			
U-235	9.0	3.0	2.0	1.3			
U-238	7.9	3.1	2.2	1.4			

946 **Table 9. TR-5 Area Factors for the Industrial Worker.**

947 Note: Ingrowth of daughter products is included in the analysis.

948 **Table 10. TR-6 Area Factors for the Industrial Worker.**

	Elevated Area of Interest (m ²)				
Nuclide	1	5	10	50	
C-14	29	12	8.3	4.2	
Cs-137	11	3.3	2.2	1.3	
Nb-94	11	3.4	2.2	1.3	
Pb-210	70	35	24	10	
Pu-242	4.9	4.1	3.7	2.9	
Ra-226	11	3.4	2.3	1.3	
Sr-90	12	3.8	2.5	1.5	
Th-229	6.7	3.0	1.6	1.3	
Th-230	11	3.5	2.3	1.4	
Th-232	11	3.4	2.3	1.3	
U-232	11	3.5	2.3	1.3	
U-234	2.9	2.4	2.2	1.8	
U-235	8.9	3.0	2.0	1.3	
U-238	7.8	3.1	2.2	1.3	

949

Note: Ingrowth of daughter products is included in the analysis.

950 **Table 11. Uncertainty analysis results.**

	DCGL (pCi/g)					
Scenario	Base Case	Quantile Uncertainty	Full Distribution Uncertainty			
Resident Farmer	7.4	4.4	7.5			
Industrial Worker	55	51	54			

951

952 Table 12. MARSSIM suggested areas for survey units.

Classification	Suggested Area	Survey Unit Area ^a		
Class 1	Up to 2,000 m ²	94 m ²		
Class 2	2,000 to 10,000 m ²	68 m ²		
Class 3	No limit	\sim 3,328 m ²		

953 a. Based on areas presented in Figure 9.

954	Appendix A		
955	Pb-210/Po-210 Laboratory Information		



ALS Group USA, Corp. 225 Commerce Drive Fort Collins, CO 80524

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February 2, 2017

Greg Bright Cabrera Services, Inc. 50 Founders Plaza, suite 207 East Hartford, CT 06108

Re: Dugway Proving Ground Sample SWMU11A2-Bias-14-Debris, Pb210

Dear Greg,

The sample in question was received initially for gamma spec analysis, which was later expanded to include Strontium-90, Radium-226 by emanation, Polonium-210, and Isotopic Thorium, Uranium and Plutonium.

Our internal prescreen for alpha and beta in this sample estimated these activities near or above 500 pCi/g. The Iso U, Th and Pu activities proved to be insignificant re the prescreen alpha. A reduced aliquot of sample was used for the initial Polonium-210 analysis. Nevertheless, the peak in the alpha spectrum was very large, and tailed into the tracer region of interest, which would cause an unacceptable bias to the result. The sample was, therefore, re-prepared (in duplicate) using a nitric acid leach of the original material. The aliquot size was reduced even further, allowing an acceptable spectrum. The duplicate value matched very well with the sample value (both near 3600 pCi/g). We believe the Polonium-210 results reported for this sample to be entirely unambiguous.

The Polonium-210 results, owing to it's relatively short half-life (with respect to the site history) bring up the question as to which nuclide in the decay chain would account be responsible. The parent nuclide, Pb-210, is an obvious possibility. However, Pb-210 was not included in the suite of analyses. And, unfortunately, the original sample and digestates had been disposed prior to these discussions. The only possible corroboration within the suite of analyses actually performed would be from the gamma spec.

In order to generate a quantified Pb-210 result from the original gamma spectroscopy results, the original data files for the spectra (raw data and calibration files) would need to be re-run through the instrument software, but this time including Pb-210 in the gamma library. This was attempted, however the necessary data files were not able to be recovered. This was due a failure (a few months after the gamma analysis) in the LIMS server. Additional attempts were made to recover the data from a backup tape, but thus far these attempts have been unsuccessful. So, with only the raw data printouts in hand, the following items may be noted.

Lead-210 has a gamma emission at 46.5 keV, and a peak at this energy was detected on each of 2 gamma counts (the sample was counted in duplicate), which used separate detectors. The evidence for the presence of Pb-210 is very strong, as there are no other "common" nuclides with an emission in this region. What remains open to question is the quantification of the Pb-210 in the sample. This arises because the gamma emission at 46.5 keV falls below the efficiency calibration curves for the gamma spectrometers which were used. The lowest energy nuclide in the efficiency curves is 59.5 keV, which is the emission for Americium-241. And, the "steepness" of the efficiency versus energy curve in this region



is considerable, so that energies differing by only 30 keV could see efficiencies differing by up to an order of magnitude. The lab does not possess a gamma calibration standard that includes Pb-210, or other nuclides with energies low enough to be of use for this purpose.

Based on the lack of reliable efficiency values for the 46.5 keV peak, the quantitation of Pb-210 can only be estimated, and even then, this estimate is subject to considerable uncertainty. That being said, a manual calculation of Pb-210 was performed, based on the raw data printouts from the original analyses, and making the assumption that the calibration curve could be extrapolated down to the 46.5 keV energy for Pb-210. These generated values of 1315 pCi/gram on one detector, and 2140 pCi/gram on the other, i.e. in the duplicate analysis. (Note that the two detectors used differ by a factor of 6x in their efficiencies for Americium-241, which is at 59.5 keV.) These values, at least, agree to within an order of magnitude with the Polonium-210 results from the alpha spec. This is reasonably within the range of expected values, assuming the Polonium-210 and Pb-210 activities to have reached equilibrium.

I hope that these discussions are of help in resolving the issues you are facing, and please contact me if there is anything more that I can provide.

Sincerely

Project Manager, ALS Ft Collins

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1	44.99	94.84	1814	⊁ 395	318	13151	1.74 a	Wide Pk
2	46.35	97.57	26373	371	147	4782	0.72 b	
3	62.89	130.59	311	164	132	4275	0.42 a	
4	74.70	154.16	1236	265	210	8930	0.82 a	
5	76.90	158.56	2682	276	210	8930	0.88 b	
5	79.17	103.1U	1052	264	210	8930	0.86 C	
2	80 E0 0/.T#	19.02	779	266	245 21 <i>4</i>	0268	0.94 a	
9	92.63	189.98	1185	342	276	12976	1.17 c	
10	185.94	376.27	1282	195	149	4108	1.03 a	
11	198.38	401.10	252	150	120	2914	0.85 a	
12	209.16	422.64	413	143	113	2583	0.85 a	
13	238.58	481.37	4654	194	113	2356	0.99 a	
14	241.62	487.44	1478	188	141	3141	1.33 b	r Mit Mindenson vie van in delete daar van wekendelike kan beskelder van eer et eeler van wer bei
15	270.17	544.45	404	149	118	2205	1.37 a	
16	277.37	558.82	102	103	83	1388	0.75 a	
17	295.16	594.35	2586	155	96 75	1580		
10 10	320 16	0V4.3/ 660 99	174	75 100	79	116E 1162	0 00 -	
20	338.30	680.47	840	104	73	1051	1.01 a	
21	351.95	707.73	4166	159	76	1146	1.15 a	
		Page 001	- 1 c	4	1 1	1 ./		
			* split	peak , coun	ds not use			705 of 1319
160437D07.SPC Analyzed by

PEAK SEARCH RESULTS

PK.	ENERGY	ADDRESS	NET/MDA	UN-	C.L.	BKG	FWHM	
#	(keV)	CHANNEL	COUNTS	CERTAINTY	COUNTS	COUNTS	(keV)	FLAG
22	409.49	822.62		76	60	765	0.97 2	
23	462.86	929.18	242	82	62	713	1.28	1
24	487.29	977.95	57	79	64	704	1.44 8	NET< CL
25	511.13	1025.56	1895	148	98	1247	2.43 8	Wide Pk
26	558.43	1120.00	171	67	50	501	1.08 a	L
27	583.38	1169.81	1474	100	52	531	1.55 a	1
28	609.50	1221.95	3083	135	63	736	1.58 a	1
29	652.04	1306.90	59	62	49	470	1.46	L
30	661.87	1326.52	113	63	49	496	1.26 a	L
31	727.41	1457.39	334	70	49	442	1.63 a	L
32	768.48	1539.38	180	65	48	456	1.54	L
33	786.15	1574.66	80	44	33	258	0.97 a	L
34	795.13	1592.59	126	62	48	424	1.64 8	L
35	803.11	1608.53	220	61	44	382	1.52 1	b
36	806.45	1615.18	51	51	41	339	1.29 0	2
37	860.89	1723.88	109	54	41	353	1.39 a	L
38	911.33	1824.60	1047	84	44	369	1.86 a	L
39	934.07	1870.01	112	65	51	438	2.22 8	L
40	964.76	1931.27	123	59	45	387	1.76 a	1
41	969.10	1939.95	547	72	45	387	1.85 1	•
42	1120.39	2242.01	645	81	52	440	2.39 a	L
43	1238.25	2477.33	214	66	48	415	2.13 8	L
44	1281.33	2563.34	58	52	41	300	2.17 a	L
45	1377.84	2756.03	138	56	42	264	2.76 8	L
46	1408.06	2816.38	55	35	27	149	1.40 s	L
47	1460.51	2921.10	3715	130	36	208	2.69 a	HiResid
48	1508.94	3017.78	64	39	29	157	1.99 a	L
49	1588.15	3175.94	57	46	36	200	2.73 a	L
50	1728.46	3456.09	107	48	35	168	3.39 a	L .
51	1764.03	3527.12	505	56	28	117	2.96 a	L
52	1846.97	3692.70	51	48	37	167	4.17 a	L

	160437D07.SPC Analyzed by												
****	********	*****	******	******	******	******	******	*****					
SEEI	CER 1	BACKG	ROUND	SUBTR	ACTR	ESULT	S Vers. 2	2.2.1					
ALS Laboratory Group - Fort Collins													
GammaScan													

Background File: DET070504.BKG (050416-7 WEEKLY BKG)													
Bkg.File Detector #: 7													
****	***********				********	**********		******					
			BACKGROU	ND SUBTRAC	T RESULTS								
8222				*********			*********						
	ENERGY	OLD NET	OLD UN-	OLD	NEW NET	NEW UN-	NEW						
PK#	(keV)	COUNTS	CERTAINTY	CR.LEVEL	COUNTS	CERTAINTY	CR.LEVEL	FLAG					
1	44.99	1814	395	318	1724	404	326						
3	62.89	311	164	132	185	196	160						
4	74.70	1236	265	210	1069	305	245						
5	76.90	2682	276	210	2532	305	237						
7	87.14	775	303	245	715	339	276						
9	92.63	1185	342	276	853	374	303						
10	185.94	1282	195	149	986	238	189						
11	198.37	252	150	120	62	210	172 N	ET <cl< td=""></cl<>					
13	238.58	4654	194	113	4358	233	158						
14	241.62	1478	188	141	1404	238	186						
17	295.16	2586	155	96	2491	200	142						
20	338.30	840	104	71	788	161	124						
21	351.95	4166	1,59	76	3863	217	147						
25	511.13	1895	148	98	401	279	227						
26	558.43	171	67	50	12	124	102 N	ET <cl< td=""></cl<>					
27	583.38	1474	100	52	1341	140	98						
28	609.50	3083	135	63	2925	169	107						
29	652.04	59	62	49	38	90	73 N	ET <cl< td=""></cl<>					
35	803.11	220	61	44	78	107	87 N	ET <cl< td=""></cl<>					
38	911.33	1047	84	44	969	120	84						
47	1460.51	3715	130	36	3508	157	84						

1764.03

160437D07.SPC Analyzed by													
******	********	*******	*******	*******	********	*****							
SEEKER	F	INAL	ACTIV	ITY RI	EPORT	Version 2.2.1							
		ALS 1	Laboratory Gro	oup - Fort	Collins								
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~													
Geo.11 / Solid													
Geo.ll / Solid													
Sample ID: 1604451-36 GS160504-1													
Sampie ID: 1604451-36 GS160504-1													
Sampling	Start:	04/21/20	016 12:00:00	Counting	Start:	05/05/2016 13:58:45							
Sampling	Stop:	04/21/20	016 12:00:00	Decay Tir	ne	3.38e+002 Hrs							
Buildup	Time	0	.00e+000 Hrs	Live Time		•••• 60000 Sec							
Sample S	Size	• • • •	8.86e+001 g	Real Time	ə	60158 Sec							
Collecti	on Efficie	ncy	. 1.0000	Spectrum	File	160437D07.SPC							
Cr. Leve	l Confiden	ce Interv	val: 95 %	Det. Limi	it Confider	ce Interval: 95 %							
			nananananan.										
REFICION	or Silos (	1 2071 (651)	Detector #: 3	/ (Detector	57)								
Eff=10/	CY FILE: (	107)(Sni)	1).EFF (Geo 1. 01*T. 4.4 07544	L MII CAL) Distante (	0.00+7.431	11/10/0015							
Eff.=104	[-7.33&+01 [-1.02E+01	+1.08E+(	01*T. 4_4.1584(	JA*I.42 ±8 с	30ビ+00×L~3] 37〒-01*T & 31	11/16/2015							
Library	File:		.FANP.LIB (F2	ANP (Fiss.	Act. and N	at. Products))							
*******													
		ME	EASURED or MDI	A CONCENTRA	TIONS								
		==========											
	N	ſ											
	ENERGY E	Conce	entration		Critical	Halflife							
Nuclide	(KeV) T	(pCi/g	)	MDA	Level	(hrs)							
	Average	1 838100	7 <i>4</i> 08-01			3 007.13							
	63.29	1.74E+00	0 +- 1.85ELOL	3 048400	1 518400	2.0277.13							
	92,50	1.84E+00	0 +- 8.07E-01	1.32E+00	6.56E-01	3.928713							
<b>U-235</b>	143.76 N	1.27E-01	L +- 1.99E-01	3.28E-01	1.63E-01	6.17E+12							
	185.72	I.D.				6.17E+12							
Pb-212	Average:x	1.16E+00	0 +- 6.17E-02			1.67E+04							
	238.63	1.17E+00	0 +- 6.25E-02	8.56E-02	4.24E-02	1.672+04							
	300.09	7.83E-01	L +- 3.83E-01	6.14E-01	3.02E-01	1.67E+04							
<b>T1-208</b>	Average:x	3.60E-01	L +- 3.68E-02			1.67E+04							
	277.36	2.06E-01	L +- 2.07E-01	3.39E-01	1.67E-01	1.67E+04							
	583.14	3.70E-01	L +- 3.86E-02	5.49E-02	2.71E-02	1.67E+04							
	860.47	2.95E-01	L +- 1.45E-01	2.28E-01	1.10E-01	1.67E+04							
Pb-214	Average:x	1.57E+00	) +- 7.24E-02	• • • •	• • • •	1.40E+07							
	295.22	1.67E+00	+-1.34E-01	1.92E-01	9.52E-02	1.40E+07							
	351.99	1.53E+00	+- 8.62E-02	1.17E-01	5.81E-02	1.40E+07							
AC-228	Average:x	1.23E+00	+-1.01E-01	• • • •		5.04E+04							
	338.40	T.00E+00	7 +- 2.04E-01	3.18E-01	1.57E-01	5.04E+04							
	377.U/	1 202.00	) T- 1.03E-Ul	2.33E-01	1.14E-01	5.U4E+04							
Sh-125	Averace."	1.20E+VU	) T- V 238-03	2.105-UI	T.02E-01	つ。U4些中U4 つ、A2型+0A							
-77-772	463.51	4.342-01	$+-1.47E_{-01}$	••••• 7.292-01	••••• 1 118-01	2.435+V4 2 /37+0/							
	Page	 004	. +- T'#\V-AT	4.40 <u>0</u> 01	ᆂᆞᆂᆂᇏᆕᇇᆍ	4 • 4 Jet V4							
	- 470												

### 160437D07.SPC Analyzed by

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### MEASURED or MDA CONCENTRATIONS

		N									
	ENERGY	E Conce	ntra	ation		Critical	Halflife				
Nuclide	(keV)	T (pCi/g		)	MDA	<b>Level</b>	(hrs)				
	427.95	N-2.92E-03	+	4.88E-02	8.20E-02	4.02E-02	2.43E+04				
Bi-214	Average	:ж 1.56E+00	+-	8.18E-02			1.40E+07				
	609.32	1.52E+00	<b>+</b> →	8.79E-02	1.12E-01	5.55E-02	1.40E+07				
	1120.28	1.79E+00	+-	2.24E-01	2.95E-01	1.44E-01	1.40E+07				
Cs-137	661.62	3.45E-02	+-	1.93E-02	3.07E-02	1.50E-02	2.64E+05				
Bi-212	727.17	1.46E+00	+-	3.04E-01	4.38E-01	2.13E-01	1.67E+04				
Cs-134	Average	:x 8.74E-03	+-	1.45E-02			1.81E+04				
	795.76	4.60E-02	+-	2.27E-02	3.59E-02	1.74E-02	1.81E+04				
	604.66	N-1.65E-02	+-	1.87E-02	3.22E-02B	1.58E-02	1.81E+04				
Eu-152	1408.08	1.32E-01	+-	8.59E-02	1.35E-01	6.43E-02	1.17E+05				
K-40	1460.75	1.66E+01	+-	7.43E-01	8.12E-01	4.00E-01	1.12E+13				
Am-241	59.54	N 1.87E-01	+-	2.91E-01	4.79E-01	2.38E-01	3.80E+06				
Eu-155	105.31	N 3.88E-02	+-	1.25E-01	2.06E-01	1.03E-01	4.35E+04				
Co-57	122.07	N-7.84E-03	÷	2.50E-02	4.15E-02	2.06E-02	6.48E+03				
Ce-144	133.53	N-2.16E-01	+-	1.75E-01	2.93E-01	1.46E-01	6.82E+03				
Ce-139	165.85	N-1.40E-02	<b>+</b> ++	2.47E-02	4.12E-02	2.04E-02	3.30E+03				
Th-227	236.00	N 1.85E+00	+-	2.66E+00	4.37E+00P	2.18E+00	1.90E+05				
Cr-51	320.07	N-1.79E-01	+-	2.19E-01	3.70E-01	1.82E-01	6.65E+02				
I-131	364.48	N-4.14E-02	+-	5.45E-02	9.29E-02	4.56E-02	1.93E+02				
Be-7	477.56	N-4.39E-02	+-	1.63E-01	2.76E-01	1.35E-01	1.28E+03				
Sb-124	602.71	N-3.53E-03	+-	2.13E-02	3.60E-02B	1.76E-02	1.44E+03				
Ag-108m	614.37	N 7.74E-03	+-	1.98E-02	3.30E-02b	1.61E-02	1.11E+06				
Ru-106	621.84	N-4.60E-02	+-	1.81E-01	3.07E-01	1.50E-01	8.84E+03				
Ag-110M	657.75	N-4.89E-03	+-	1.90E-02	3.23E-02B	1.57E-02	6.00E+03				
Nb-94	702.50	N-1.12E-02	+-	2.07E-02	3.53E-02	1.73E-02	1.78E+08				
Nb-95	765.82	N 3.58E-02	+-	3.39E-02	5.42E-02R	2.66E-02	1.54E+03				
Co-58	810.75	N 2.29E-02	+-	3.34E-02	5.43E-02r	2.67E-02	1.70E+03				
Mn-54	834.81	N 1.77E-03	+-	2.08E-02	3.50E-02	1.71E-02	7.49E+03				
Sc-46	889.26	N-1.07E-02	+-	2.31E-02	3.96E-02	1.93E-02	2.01E+03				
Pa-234m	1001.03	N 1.93E+00	+-	3.79E+00	6.30E+00	3.06E+00	3.925+13				
Eu-154	1004.80	N-6.70E-02	+-	1.26E-01	2.16E-01	1.05E-01	7.45E+04				
Fe-59	1099.22	N-5.87E-02	+-	5.55E-02	9.69E-02	4.72E-02	1.08E+03				
Zn-65	1115.52	N-6.53E-02	+-	7.27E-02	1.27E-01R	6.23E-02	5.85E+03				
Co-56	1238.28	N 1.64E-01	+-	8.62E-02	1.34E-01r	6.59E-02	1.86E+03				
Na-22	1274.54	N 2.39E-02	+-	2.53E-02	4.14E-02B	2.00E-02	2.28E+04				
Co-60	1332.51	N 1.63E-03	+-	2.60E-02	4.40E-02	2.13E-02	4.62E+04				
Al-26	1808.65	N 2.11E-02	+-	2.23E-02	3.64E-02	1.74E-02	6.31E+09				

MEASURED TOTAL: 3.04E+01 +- 9.63E+00 pCi/g

160437D07.SPC Analyzed by

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### UNKNOWN, SUM OF ESCAPE PEAKS

PK.	ENERGY	ADDRESS	NET	UN-	C.L.	BKG	FWEM	
#	(keV)	CHANNEL	COUNTS	CERTAINTY	COUNTS	COUNTS	(keV)	FLAG
1	44.99	94.84	1724	404	326	13151	1.74	Unknown
2	46.35	97.57	26373	371	147	4782	0.72	Unknown
4	74.70	154.16	1069	305	245	8930	0.82	Unknown
5	76.90	158.56	2532	305	237	8930	0.88	Unknown
6	79.17	163.10	1052	264	210	8930	0.86	Unknown
7	87.14	179.02	715	339	276	11122	0.94	Unknown
8	89.69	184.11	719	266	214	9268	0.75	Unknown
11	198.37	401.10	62	210	172	2914	0.85	Deleted
12	209.16	422.64	413	143	113	2583	0.85	Unknown
14	241.62	487.44	1404	238	186	3141	1.33	Unknown
15	270.17	544.45	404	149	118	2205	1.37	Unknown
19	328.15	660.22	174	100	79	1165	0.99	Unknown
22	409.49	822.62	98	76	60	765	0.97	Unknown
24	487.29	977.95	57	79	64	704	1.44	Deleted
25	511.13	1025.56	401	279	227	1247	2.43	Unknown
26	558.43	1120.00	12	124	102	501	1.08	Deleted
29	652.04	1306.90	38	90	73	470	1.46	Deleted
32	768.48	1539.38	180	65	48	456	1.54	Unknown
33	786.15	1574.66	80	44	33	258	0.97	Unknown
35	803.11	1608.53	78	107	87	382	1.52	Deleted
36	806.45	1615.18	51	51	41	339	1.29	Unknown
39	934.07	1870.01	112	65	51	438	2.22	Unknown
40	964.76	1931.27	123	59	45	387	1.76	Unknown
43	1238.25	2477.33	214	66	48	415	2.13	Unknown
44	1281.33	2563.34	58	52	41.	300	2.17	Unknown
45	1377.84	2756.03	138	56	42	264	2.76	Unknown
48	1508.94	3017.78	64	39	29	157	1.99	Unknown
49	1588.15	3175.94	57	46	36	200	2.73	Unknown
50	1728.46	3456.09	107	48	35	168	3.39	Unknown
51	1764.03	3527.12	466	84	59	117	2.96	Unknown
52	1846.97	3692.70	51	48	37	167	4.17	Unknown

c:\SEEKER\BIN\160437d07.res Analysis Results Saved.

	160401D09.SPC Analyzed by 55 44												
****													
SER	KER	GAMM	A ANA	LYSIS	RESU	LTS P	S Versi	on 1.8.4					
			ALC Labors			1.4							
ALS Laboratory Group - Fort Collins													
****	*******	******	*****	**********	LIL :**********	********		and and a star at the star at the star at					
Geo.11 / Solid													
Samp	le ID: 10	504451-36D	GS160504-	1									
Samp	ling Star	rt: 04/	21/2016 12	:00:00   Co	unting Sta:	rt: 05	/06/201	6 13:36:00					
Samp	ling Stop	p: 04/:	21/2016 12	:00:00 De	cay Time.		. 3.6	2E+002 Hrs					
Buil	dup Time.	• • • • •	. 0.00E+0	00 Hrs   Li	ve Time .		• •	60000 Sec					
Samp	le Size .		8.86E	+001 g   Re	al Time .		• •	60161 Sec					
COTT	ection El	LICTOUCA	• • • •		c. File .	• • • • •	1604	401D09.SPC					
			Detect										
Ener	ov(keV)=	-2.35 + (	0 501*Ch ±	0 00E+00*C	BLECCOF 9)	3.00+0-43	05/06/	2010					
FWIN	(keV) =	0.68 + 1	$0.012 \times En +$	5.65E-04*E	$m^2 + 0.001$	5+00*CH~3	11/06/2	2016 2016					
		0100 .	Where	En = Sort(E	nerov in k	2400-211-3 277)	TT/00/7	2012					
					eergy in A								
Sear	ch Sensit	ivity: 1.0	00   Sigma	Multiplier	: 2.00   S	arch Sta	rt/End:	80/4000					
	===========				*********			*======;;					
			PE	AK SEARCH R	esults								
====				*********			*******						
PK.	ENERGY	ADDRESS	NET/MDA	UN-	C.L.	BKG	FWHM						
Ŧ	(KeV)	CHANNEL	COUNTS	CERTAINTY	COUNTS	COUNTS	(keV)	FLAG					
	40 35	95 15	20172	705									
	20133	03+73	201/3	700	264	31233	1.45 8	HIROSID					
2	46.43	97.27	930015	1993	413	21026	1 02 1	Wide PK					
3	63.11	130.53	640	257	207	10547	0 41 2	nikesia					
4	74.81	153.85	2739	348	207	15043	0.11						
5	76.98	158.19	5000	361	273	15043	0.70 0	•					
6	79.23	162.66	1496	341	273	15043	0.75	1					
7	87.24	178.65	1160	305	244	12020	0.85 a						
8	89.83	183.80	1109	304	244	12020	0.82 1	-					
9	92.89	189.90	1453	389	314	16828	1.13 c	- -					
10	99.45	203.00	58	191	157	6069	0.43 a	NET< CL					
11	129.15	262.22	411	245	199	7306	1.02 a	i i					
12	130.07	264.05	-22	148	122	3653	0.45 1	NET< CL					
13	186.09	375.75	1152	196	151	3897	1.11 a						
14	209.31	422.07	391	163	130	2904	1.08 a						
15	219.18	441.74	77	133	108	2159	1.00 a	NET< CL					
16	224.20	451.76	82	100	81	1439	0.73 E	)					
17	238.74	480.76	3910	175	101	1871	0.98 a	HiResid					
18	242.01	487.26	1219	168	126	2495	1.27 b	HiResid					
70 TA	209.28	521.71	87	122	99	1673	1.16 a	NET< CL					
20	270.35	543.79	406	158	126	2192	1.68 a						
		rage 001											

711 of 1319

160401D09.SPC Analyzed by

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### PEAK SEARCH RESULTS

PK.	ENERGY	ADDRESS	NET/MDA	UN-	C.L.	BKG	FWHM		
#	(keV)	CHANNEL	COUNTS	CERTAINTY	COUNTS	COUNTS	(keV)	FLAG	
21	277.48	558.01	141	93	74	1102	0.81	a	
22	295.35	593.04	1912	137	87	1293	1.08	a -	
23	300.27	603.45	180	75	58	739	0.60	b	
24	328.08	658.90	204	118	95	1322	1.45	a	
25	338.53	679.75	653	106	76	995	1.18	a	
20	342.17	687.UI	85	74	59	711	0.85	b	
27	352.12	706.85	3185	143	73	901	1.21	a	
28	393.21	788.79	49	83	67	771	1.09	a Net<	CL
29	409.78	821.82	71	80	64	702	1.08	a	
30	463.30	928.55	168	69	52	542	1.08	a	
31	511.12	1023.92	1668	139	92	1099	2.46	a Wide	Pk
32	559.07	1119.52	116	72	56	549	1.44	a	
33	570.80	1142.91	40	53	42	379	0.92	a net<	CL
34	583.61	1168.46	1082	93	54	507	1.53	a	
35	609.70	1220.50	2166	120	62	636	1.61	a	
36	651.27	1303.39	21	36	28	197	0.68	a NET<	CL
37	662.12	1325.02	172	80	62	572	1.93	a	
38	665.48	1331.71	115	74	58	524	1.80	b	
39	694.32	1389.23	53	61	49	446	1.30	a	
40	727.81	1456.01	199	64	48	393	1.41	a	
41	768.28	1536.72	165	70	53	441	1.77	8.	
42	786.58	1573.21	55	52	41	313	1.37	a	
43	795.61	1591.22	117	63	49	373	1.84	a Wide	Pk
44	804.21	1608.36	312	100	77	644	3.08	ь	
45	861.29	1722.20	110	55	41	318	1.70	a	
46	911.66	1822.63	700	78	47	350	2.12	a	
47	934.43	1868.04	60	56	45	335	1.93	a	
48	965.20	1929.40	97	50	38	284	1.49	a	
49	969.38	1937.74	335	68	48	379	1.89	b	
50	1036.91	2072.39	23	28	22	118	0.83	a	
51	1120.78	2239.63	437	70	46	339	2.07	a	
52	1238.76	2474.90	151	65	50	366	2.49	a	
53	1377.56	2751.68	96	38	27	136	1.88	a	
54	1379.14	2754.85	26	23	17	74	0.96	Ь	
55	1407.90	2812.18	23	28	22	109	1.13	8	
56	1460.97	2918.01	2634	112	36	195	3.02	a	
57	1508.55	3012.89	23	49	40	223	3.17	a NET<	CL
58	1729.86	3454.20	50	36	27	119	2.38	8	
59	1764.38	3523.05	318	50	29	124	3.11	a	

160401D09.SPC A	nalvzed	bv
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SEEKER BACKGROUND SUBTRACT RESULTS Vers. 2.2.1

### ALS Laboratory Group - Fort Collins

GammaScan

Background File:. . . . . DET090504.BKG (050416-9 WEEKLY BKG)

Bkg.File Detector #: 9

### BACKGROUND SUBTRACT RESULTS

PK#	ENERGY OLD NET # (kev) Counts		OLD UN- OLD CERTAINTY CR.LEV		NEW NET NEW UN- COUNTS CERTAINTS		NEW CR.LEVEI	L FLAG
2	46.43	930015	1993	413	929669	1999	433	
3	63.11	640	257	207	242	303	248	NET <cl< td=""></cl<>
4	74.81	2739	348	273	2584	373	295	
5	76.98	5000	361	273	4882	377	288	
7	87.24	1160	305	244	1129	320	258	
9	92.89	1453	389	314	900	430	350	
13	186.09	1152	196	151	948	237	188	
17	238.74	3910	175	101	3734	226	156	
22	295.35	1912	137	87	1868	157	108	
27	352.12	3185	143	73	3053	189	126	
31	511.12	1668	139	92	586	267	216	
32	559.07	116	72	56	25	119	98	NET <cl< td=""></cl<>
33	570.80	40	53	42	6	117	96	NET <cl< td=""></cl<>
34	583.61	1082	93	54	1025	138	100	
35	609.70	2166	120	62	2109	158	106	
36	651.27	21	36	28	-5	67	55	NET <cl< td=""></cl<>
39	694.32	53	61	49	-41	187	154	NET <cl< td=""></cl<>
44	804.21	312	100	77	246	132	106	
46	911.66	700	78	47	644	1.20	89	
56	1460.97	2634	112	36	2493	132	71	

160401D09.SPC Analyzed by	
*****************************	***********
SEEKER FINAL ACTIVI	TY REPORT Version 2.2.1
ALS Laboratory Grou	p - Fort Collins
GanmaS	can
***********	*************
Geo.11 /	Solid
Sample ID: 1604451-36D G8160504-1	
Sampling Start, $04/21/2016$ 12.00.00	
Sampling Stop: $04/21/2010 12:00:00$	Councing Start: 05/06/2016 13:36:00
Buildup Time 0.000+000 Hrs	
Sample Size 8.86e+001 g	Real Time
Collection Efficiency 1.0000	Spectrum File
Cr. Level Confidence Interval: 95 %	Det. Limit Confidence Interval: 95 %
Detector #: 9	(Detector 9)
Efficiency File: (D09)(Sh11).EFF (Geo 11	Eff Cal)
Eff.=1/[2.69E-01*En^-1.27E+00 + 9.61E+01	*En^9.60E-01] 11/19/2015
Library File:	P (Fiss. Act. and Nat. Products))
	99999999999999999999999999999999999999
Measured of MDA	CONCENTRATIONS
N	
ENERGY E Concentration	Critical Halflife
Nuclide (keV) T (pCi/g )	MDA Level (hrs)
***************************************	
Th-234 92.50 1.27E+00 +- 6.08E-01	9.9 <b>4E-01 4.95E-01 3.92E+1</b> 3
U-235 143.76 N 9.24E-02 +- 2.27E-01	3.75E-01 1.86E-01 6.17E+12
185.72 I.D	· · · · · · · · 6.17E+12
Pb-212 Average:x 1.15E+00 +- 6.87E-02	••••••••••••••••••••••••••••••••••••••
238.63 1.16E+00 +- 6.98E-02	9.74E-02 4.83E-02 1.67E+04
300.09 8.93E-01 +- 3.74E-01	5.88E-01 2.87E-01 1.67E+04
T1-208 Average:x 3.62E-01 +- 4.61E-02	••••••••••••••••••••••••••••••••••••••
277.36 $3.40E-01 + - 2.24E-01$	3.63E-01 1.78E-01 1.67E+04
583.14 3.62E-U1 +- 4.87E-02	7.18E-02 3.54E-02 1.67E+04
300.47 $3.835-01 + 1.90E-01$	2.98E-01 1.44E-01 1.67E+04
PD-214 AVErage:X 1.525+00 +- 7.515-02	···· · · · · · · · · · · · · · · · · ·
351 99 1 528±00 += 1.29E=01 .	1.80E-01 8.87E-02 1.40E+07
$A_{C-228}$ Average v 1 05E±00 ±= 1 11E_01	1.2/E-UI 0.29E-U2 1.4UE+U7 E 04m-04
338.40  1.04E+00  += 1.68E-01	・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・
911.07 1.13E+00 +- 2.09E-01	3.16E=01 1.56E=01 5.04E=04
968.90 1.01E+00 +- 2.07E-01	
Sb-125 Average:x 2.38E-02 +- 4.81E-02	2.478±04
463.51 3.84E-01 +- 1.57E-01	2.46E-01 $1.20E-01$ $2.43E+04$
427.95 N-1.35E-02 +- 5.06E-02	8.58E-02 4.19E-02 2.43E+04
Bi-214 Average:x 1.43E+00 +- 9.71E-02	· · · · · · · · · · · · · · · · · · ·
609.32 1.40E+00 +- 1.05E-01	1.43E-01 7.05E-02 1.40E+07
Page 004	

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### MEASURED or MDA CONCENTRATIONS

******	***************************************											
		N										
	ENERGY	E	Conce	ntra	ation		Critical	Halflife				
Nuclide	(keV)	T	(pCi/g		)	MDA	Level	(hrs)				
	1120.28		1.58E+00	+-	2.52E-01	3.42E-01	1.66E-01	1.40E+07				
Cs-137	661.62		6.71E-02	+-	3.11E-02	4.95E-02	2.42E-02	2.64E+05				
Bi-212	727.17		1.11E+00	+-	3.59E-01	5.46E-01	2.65E-01	1.67E+04				
Cs-134	Average	:ж	1.40E-02	+-	1.73E-02		• • • •	1.81E+04				
	795.76		5.45E-02	+-	2.96E-02	4.70E-02	2.29E-02	1.81E+04				
	604.66	N-	-6.95E-03	+-	2.13E-02	3.62E-02B	1.77E-02	1.81E+04				
Co-56	Average	:ж	1.40E-01	+-	5.80E-02	• • • •	• • • •	1.86E+03				
	1037.83		9.58E-02	+	1.17E-01	1.93E-01	9.10E-02	1.86E+03				
	1238.28		1.54E-01	+-	6.66E-02	1.04E-01	5.08E-02	1.86E+03				
Eu-152	1408.08		7.34E-02	+-	9.05E-02	1.49E-01	7.01E-02	1.17E+05				
K-40	1460.75		1.60E+01	+-	8.45E-01	9.26E-01	4.54E-01	1.12E+13				
Am-241	59.54	N	1.01E-02	+-	8.31E-02	1.37E-01	6.83E-02	3.80E+06				
Eu-155	105.31	N	2.59E-02	+-	9.90E-02	1.64E-01	8.13E-02	4.35E+04				
Co-57	122.07	N-	-2.33E-02	+-	2.48E-02	4.13E-02	2.05E-02	6.48E+03				
Ce-144	133.53	N-	·1.26E-02	+	1.70E-01	2.82E-01	1.40E-01	6-82E+03				
Ce-139	165.85	N	2.30E-03	+-	2.51E-02	4.15E-02	2.06E-02	3.30E+03				
Th-227	236.00	N	3.19E-02	+	1.31E-01	2.18E-01B	1.08E-01	1,90E+05				
Cr-51	320.07	N-	8.47E-02	+-	2.45E-01	4.13E-01	2.03E-01	6.65E+02				
I-131	364.48	N	1.47E-03	+-	7.55E-02	1.27E-01	6.21E-02	1.93E+02				
Be-7	477.56	N	7.08E-04	+-	1.73E-01	2.92E-01	1.42E-01	1.28E+03				
Sb-124	602.71	N	5.53E-03	+-	2.47E-02	4.14E-02	2.02E-02	1.44E+03				
Ag-108m	614.37	N	1.13E-02	+-	2.14E-02	3.56E-02b	1.73E-02	1.11E+06				
Ru-106	621.84	N-	7.21E-02	+-	1.93E-01	3.30E-01	1.61E-01	8.842+03				
Ag-110M	657.75	N	3.36E-02	+-	2.93E-02	4.63E-02R	2.27E-02	6.00E+03				
Nb-94	702.50	N-	4.61E-03	<b>+-</b>	2.41E-02	4.08E-02	1.99E-02	1.78E+08				
Nb-95	765.82	N-	2.08E-02	+-	3.69E-02	6.36E-02R	3.12E-02	1.54E+03				
Co-58	810.75	N	5.87E-04	+	3.50E-02	5.88E-02r	2.88E-02	1.70E+03				
Mn-54	834.81	N-	1.45E-03	+-	2.19E-02	3.73E-02	1.81E-02	7.49E+03				
Sc-46	889.26	N	1.54E-03	+-	2.34E-02	3.97E-02	1.92E-02	2.01E+03				
Pa-234m	1001.03	N	1.25E+00	+-	3.962+00	6.65E+00	3.21E+00	3.92E+13				
Eu-154	1004.80	N	3.29E-02	+-	1.30E-01	2.19E-01	1.06E-01	7.452+04				
Fe-59	1099.22	N	2.41E-02	+-	5.34E-02	8.93E-02	4.30E-02	1.082+03				
Zn-65	1115.52	N-	4.49E-02	+-	6.84E-02	1.20E-01R	5.87E-02	5.85E+03				
Na-22	1274.54	N	1.96E-02	+-	2.62E-02	4.33E-02	2.08E-02	2.28E+04				
Co-60	1332.51	N	4.05E-03	+-	2.49E-02	4.24E-02	2.03E-02	4.62E+04				
A1-26	1808.65	N	1.23E-02	<b>+</b> -	2.36E-02	4.26E-02	2.01E-02	6.31E+09				
MEASURE	D TOTAL:		2.57E+01	+	7.60E+00	pCi/g						
	*********	:==		===	============	********						
			UN	KNO	WN, SUM OI	ESCAPE PEA	KS					

PK.	ENERGY	ADDRESS	NET	UN-	C.L.	BKG	FWHM	FLAG
#	(keV)	CHANNEL	COUNTS	CERTAINTY	COUNTS	COUNTS	(keV)	
1	40.35	85.15 Page 005	28173	786	584	31539	1.45	Unknown

160401D09.SPC Analyzed by

## 

### UNKNOWN, SUM OF ESCAPE PEAKS

### 

PK.	ENERGY	ADDRESS	NET	UN-	C.L.	BKG	FWHM	
#	(keV)	CHANNEL	COUNTS	CERTAINTY	COUNTS	COUNTS	(keV)	FLAG
2	46.43	97.27	929669	1999	433	21026	1.02	Unknown
3	63.11	130.53	242	303	248	10547	0.41	Deleted
4	74.81	153.85	2584	373	295	15043	0.78	Unknown
5	76.98	158.19	4882	377	288	15043	0.87	Unknown
6	79.23	162.66	1496	341	273	15043	0.75	Unknown
7	87.24	178.65	1129	320	258	12020	0.85	Unknown
8	89.83	183.80	1109	304	244	12020	0.82	Unknown
10	99.45	203.00	58	191	157	6069	0.43	Deleted
11	129.15	262.22	411	245	199	7306	1.02	Unknown
12	130.07	264.05	-22	148	122	3653	0.45	Deleted
14	209.31	422.07	391	163	130	2904	1.08	Unknown
15	219.18	441.74	77	133	108	2159	1.00	Deleted
16	224.20	451.76	82	100	81	1439	0.73	Unknown
18	242.01	487.26	1219	168	126	2495	1.27	Unknown
19	259.28	521.71	87	122	99	1673	1.16	Deleted
20	270.35	543.79	406	158	126	2192	1.68	Unknown
24	328.08	658.90	204	118	95	1322	1.45	Unknown
26	342.17	687.01	85	74	59	711	0.85	Unknown
28	393.21	788.79	49	83	67	771	1.09	Deleted
29	409.78	821.82	71	80	64	702	1.08	Unknown
31	511.12	1023.92	586	267	216	1099	2.46	Unknown
32	559.07	1119.52	25	119	98	549	1.44	Deleted
33	570.80	1142.91	6	117	96	379	0.92	Deleted
36	651.27	1303.39	-5	67	55	197	0.68	Deleted
38	665.48	1331.71	115	74	58	524	1.80	Unknown
39	694.32	1389.23	-41	187	154	446	1.30	Deleted
41	768.28	1536.72	165	70	53	441	1.77	Unknown
42	786.58	1573.21	55	52	41	313	1.37	Unknown
44	804.21	1608.36	246	132	106	644	3.08	Unknown
47	934.43	1868.04	60	56	45	335	1.93	Unknown
48	965.20	1929.40	97	50	38	284	1.49	Unknown
53	1377.56	2751.68	96	38	27	136	1.88	Unknown
54	1379.14	2754.85	26	23	17	74	0.96	Unknown
57	1508,55	3012.89	23	49	40	223	3.17	Deleted
58	1729.86	3454.20	50	36	27	119	2.38	Unknown
59	1764.38	3523.05	318	50	29	124	3.11	Unknown

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957	Appendix B

# 958 **RESRAD ONSITE Parameter Values**

959

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RESRAD ONSIT	E					IN	PUT PARAMET	ER		
Parameter	Code	Default	Value	Units			Justification			Reference
		_	_	CHANC	<b>GE TITLES</b>					
Internal dose factor library	NA	NA	FGR-11	NA	Federal Guidance	Report 11 Dose F	Factors required by	NRC.		NUREG-1757
External dose factor library	NA	NA	FGR-12	NA	Federal Guidance	Report 12 Dose F	Factors required by	NRC.		NUREG-1757
Cut-off ½ life	NA	180	180	days	Cut-off for daught	er products (prog	eny) for in-growth	calculation.		NA
		-		SET PA	ATHWAY					
External gamma	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Inhalation (w/o radon)	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Plant ingestion	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Meat ingestion	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Milk ingestion	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Aquatic foods	NA	Active	Inactive	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Drinking water	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Soil ingestion	NA	Active	Active	unitless	Site Conceptual M	odel, Resident Ga	ardener.			NA
Radon	NA	Inactive	Inactive	unitless	NUREG-1757, Vo	l. 2, Section J.4 st	tates that the Radon	n pathway should b	e turned off.	NUREG-1757
			MOI	DIFY DATA -	– Soil Concentratio	ns				
Activity units	NA	pCi	pCi	NA	Standard reporting	units.				NA
Dose units	NA	mrem	mrem	NA	Standard reporting	units.				NA
Basic radiation dose limit	NA	NA	25	mrem/yr	NRC TEDE limit f	or unrestricted sit	te release.			10 CFR 20.1402
Nuclide concentration	S(i)	NA	1	pCi/g	A unit concentration	on was used as the	e input value for ead	ch COC.		NA
		-	_	- Tra	insport					
Unsaturated Zone	NA	1	1	unitless	One UZ was inclu	ded in the CSM.				NA
Time since material placement	TI	0	0	yr	Parameter only ap	plicable when use	ed to estimate distri	bution coefficients	5.	NA
Ground water Concentration	W(i)	NA	NA	pCi/L	Parameter only ap	plicable when use	ed to estimate distri	bution coefficients	5.	NA
Solubility Limit	SOLUBK0(i)	0	0	Mol/L	Parameter only ap	plicable when use	ed to estimate distri	bution coefficients	5.	NA
Leach Rate	RLEACH(i)	0	0	1/yr	Parameter only ap	plicable when use	ed to estimate distri	bution coefficients	5.	NA
Plant/Soil Ratio	NA	Variable	Unchecked	NA	Parameter only ap	plicable when use	ed to estimate distri	bution coefficients	5.	NA
	Distribu	tion coefficient	s, Kd (Contamin	nated Zone/ U	Insaturated Zone / S	Saturated Zone)				
	DCACTC(i)	0	5			Soil Solid/Liquid	Partitioning Coof	figionts K.S. am ³	/a	
Carbon	DCACTU1(i)	0	5	$cm^{3}/g$	(Sheppard and Thibault 1990) Sheppard and					
	DCACTS(i)	0	5							
	DCACTC(i)	4,600	280		Element	Sand	Loam	Clay	Organic	
Cesium	DCACTU1(i)	4,600	280	$cm^{3/g}$	Carbon	5	20	1	70	Sheppard and Thibault, 1990
	DCACTS(i)	4,600	280	6	Cesium	280	4,600	1,900	270	

RESRAD ONSITE			INPUT PARAMETER									
Parameter	Code	Default	Value	Units			Justification			Reference		
	DCACTC(i)	0	160		Niobium	160	550	900	2,000			
Niobium	DCACTU1(i)	0	160	cm ³ /g	Lead	270	16,000	550	22,000	Sheppard and Thibault, 1990		
	DCACTS(i)	0	160		Plutonium	550	1,200	5,100	1,900			
	DCACTC(i)	100	270		Radium	500	36,000	9,100	2,400			
Lead	DCACTU1(i)	100	270	$cm^3/g$	Thorium	3 200	3 300	5 800	89.000	Sheppard and Thibault, 1990		
	DCACTS(i)	100	270		Uranium	35	15	1.600	410			
	DCACTC(i)	2,000	550					1,000				
Plutonium	DCACTU1(i)	2,000	550	$cm^3/g$						Sheppard and Thibault, 1990		
	DCACTS(i)	2,000	550									
	DCACTC(i)	70	500									
Radium	DCACTU1(i)	70	500	$cm^{3}/g$						Sheppard and Thibault, 1990		
	DCACTS(i)	70	500	C								
	DCACTC(i)	30	15									
Strontium	DCACTU1(i)	30	15	$cm^{3/g}$						Sheppard and Thibault, 1990		
	DCACTS(i)	30	15	0								
	DCACTC(i)	60,000	3,200									
Thorium	DCACTU1(i)	60,000	3,200	$cm^{3}/g$						Sheppard and Thibault, 1990		
	DCACTS(i)	60,000	3,200									
	DCACTC(i)	50	35									
Uranium	DCACTU1(i)	50	35	$cm^{3}/g$						Sheppard and Thibault, 1990		
	DCACTS(i)	50	35									
	·		MO	DIFY DATA	– Calculation Time	es						
Times for calculation	T(t)	1 to 1,000	1 to 1,000	yr	Standard calculatio	n times over 1,000	)-year evaluation p	eriod.		NA		
			MOD	IFY DATA -	- Contaminated Zo	ne				_		
Contaminated zone area	AREA	10,000	1033 (TR-5) 906.7 (TR-6)	m ²	P2 Physical Parame over an area resulti cubic yards in CAE rectangular soil vol 155 m ³ (203 yd ³ ). T The model area wa long by 20 ft wide	eter. Assumed all ng in a depth of 0. BRERA (2016). Th ume that was46 ft Trench TR-6 waste s conservatively a by up to 6 ft deep,	waste was exhumed 15 m Trench TR-5 ne model area was o long by 17 ft wide volume estimate is ssumed to be a rect which equals 136	and brought to surf waste volume estim conservatively assun by up to 7 ft deep, v s 165 CY in CABRE angular soil volume m ³ (178 yd ³ )).	face and spread hate is 194 ned to be a which equals ERA (2016). that was 40 ft	NA		
Contaminated zone thickness	THICK0	2	0.15 (TR-5) 0.15 (TR-6)	m	P2 Physical Parame TR-5 calculated as TR-6 calculated as	NA						
Length parallel to aquifer	LCSPAQ	100	18.1 (TR-5) 17.0 (TR-6)	m	P2 Physical Parame source with an area	eter. Based on a ci	rcular source with a minated zone area	a radius of 2. Based above.	on a circular	NA		

RESRAD ONSITE				INPUT PARAMETER							
Parameter	Code	Default	Value	Units	Justification	Reference					
	_		MO	DIFY DATA	– Cover / Hydrology						
Cover depth	COVER0	0	0	m	P2 Physical Parameter. No cover material was assumed.	NA					
Density of contaminated zone	DENSCS	1.5	1.51	g/cm ³	P1 Physical Parameter. Mean Value from NUREG/CR-6697, Attachment C, Table 3.1-1.	NA					
Contaminated zone erosion rate	VCS	0.001	1E-30	m/yr	P2 Physical Parameter. No erosion is assumed since SWMU 11 is located in the remote southwest portion of DPG and lies within a small canyon on the east side of Granite Mountain.	NA					
Contaminated zone total porosity	TPCS	0.4	0.43	unitless	P2 Physical Parameter. Mean value selected for sand in Table 3.2-1 in NUREG/CR-6697.	NUREG/CR-6697					
Contaminated zone field capacity	FCCS	0.2	0.1	unitless	P3 Physical Parameter. Value for sand in Table 2.16.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015					
Contaminated zone hydraulic conductivity	HCCS	10	100	m/yr	P2 Physical Parameter. Value for sand in Table 2.4.1 of the RESRAD Data Collection Handbook (Yu et al. 2015). As noted by Yu et al. 2016, within an anisotropic geological formation, the vertical component of the saturated hydraulic conductivity is usually smaller (by one to two orders of magnitude) than the horizontal component. Therefore, the mean value was reduced by two orders of magnitude for the vertical hydraulic conductivity.	Yu et al. 2015					
Contaminated zone b parameter	BCS	5.3	4.05	m ²	P2 Physical Parameter. The b parameter was selected for sand from Table 2.5.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015					
Humidity in air	HUMID	8	NA	g/m ³	NA. Tritium is not a radionuclide of concern for the site. Humidity input is only required if Tritium is present.	NA					
Evapotranspiration coefficient	EVAPTR	0.5	0.5	unitless	P2 Physical Parameter. RESRAD default used.	NA					
Wind speed	WIND	2	2.68	m/sec	P2 Physical Parameter.	Foster Wheeler 1997					
Precipitation	PRECIP	1	0.1986	m/yr	P2 Physical Parameter. Average annual rainfall (7.82 inches/yr) measured at the Station:(422257) DUGWAY from 1950 to 2006 ( <u>https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?utdugw</u> ).	Desert Research Institute Website					
Irrigation	RI	0.2	0.1125	m/yr	P3 Physical Parameter. The value of 0.1125 used in NUREG/CR-6697 was selected.						
Irrigation mode	IDITCH	Overhead	Overhead	unitless	P3 Physical Parameter. Overhead irrigation was selected.	NA					
Runoff coefficient	RUNOFF	0.2	0.4	unitless	P2 Physical Parameter. Site-specific runoff coefficient was calculated using the data provided in NUREG/CR-6697, Att. C, Table 4.2-1 assuming flat cultivated land with intermediate combination of clay and loam.	NUREG/CR-6697					
Watershed area for nearby stream or pond	WAREA	1.00 E+06	NA	m ²	P3 Physical Parameter. Surface water and aquatic food not considered.	NA					
Accuracy for Water / Soil computations	EPS	0.001	0.001	unitless	This is a RESRAD model-related parameter for computational convergence and calculation time.	NA					
	• •		M	ODIFY DAT.	A – Saturated Zone						
Saturated zone density	DENSAQ	1.5	1.51	g/cm ³	P1 Physical Parameter. Mean Value from NUREG/CR-6697, Attachment C, Table 3.1-1.	NA					
Saturated zone total porosity	TPSZ	0.4	0.43	unitless	P2 Physical Parameter. Mean PDF value selected for sand in Table 3.2-1 in NUREG/CR-6697.	NUREG/CR-6697					
Saturated zone effective porosity	EPSZ	0.2	0.383	unitless	P1 Physical Parameter. Mean of PDF for sand provided in NUREG/CR-6697, Attachment C, Table 3.3-1, was used.	NUREG/CR-6697					
Saturated zone field capacity	FCSZ	0.2	0.1	unitless	P3 Physical Parameter. Value for sand in Table 2.16.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015					

RESRAD ONSITE					INPUT PARAMETER	
Parameter	Code	Default	Value	Units	Justification	Reference
Saturated zone hydraulic conductivity	HCSZ	100	5,550	m/yr	P2 Physical Parameter. Value for sand in Table 2.4.2 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Saturated zone hydraulic gradient	HGWT	0.02	0.02	unitless	P2 Physical Parameter. RESRAD default used.	NA
Saturated zone b parameter	BSZ	5.3	4.05	m ²	P2 Physical Parameter. The b parameter was selected for sand from Table 2.5.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Water table drop rate	VWT	0.001	0	m/yr	P3 Physical Parameter. No water table drop due to pumping was assumed.	NA
Well pump intake depth (m below water table)	DWIBWT	10	10	m	P2 Physical Parameter. RESRAD default used.	NA
Model: Non-dispersion (ND) or Mass-Balance (MB)	MODEL	ND	ND	unitless	The area of contamination is approximately 1,000 m ² ; therefore, the non-dispersion model was assumed.	NA
Well pumping rate	UW	250	250	m ³ /yr	P2 Physical Parameter. RESRAD default used.	NA
			Ν	<b>IODIFY DA</b>	ΓA – Unsaturated	
Number of unsaturated strata	NS	1	1	unitless	Based upon site-specific hydrogeology one UZ was modeled.	NA
Unsaturated zone thickness	H(1)	4	18.6	m	P1 Physical Parameter. Depth to groundwater at SWMU-11 is approximately 61 ft bgs based on water-level measurements from MW01.	Parsons 2009
Unsaturated zone density	DENSUZ(1)	1.5	1.51	g/cm ³	P1 Physical Parameter. Mean Value from NUREG/CR-6697, Attachment C, Table 3.1-1.	NA
Unsaturated zone total porosity	TPUZ(1)	0.4	0.43	unitless	P2 Physical Parameter. Mean value selected for sand in Table 3.2-1 in NUREG/CR-6697.	NUREG/CR-6697
Unsaturated zone effective porosity	EPUZ(1)	0.2	0.383	unitless	P1 Physical Parameter. Mean of PDF for sand provided in NUREG/CR-6697, Attachment C, Table 3.3-1, was used.	NUREG/CR-6697
Unsaturated zone field capacity	FCUZ(1)	0.2	0.1	unitless	P3 Physical Parameter. Value for sand in Table 2.16.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Unsaturated zone hydraulic conductivity	HCUZ(1)	10	100	m/yr	P2 Physical Parameter. Value for sand in Table 2.4.1 of the RESRAD Data Collection Handbook (Yu et al. 2015). As noted by Yu et al. 2016, within an anisotropic geological formation, the vertical component of the saturated hydraulic conductivity is usually smaller (by one to two orders of magnitude) than the horizontal component. Therefore, the mean value was reduced by two orders of magnitude for the vertical hydraulic conductivity.	Yu et al. 2015
Unsaturated zone b parameter	BUZ(1)	5.3	4.05	m ²	P2 Physical Parameter. The b parameter was selected for sand from Table 2.5.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
			]	MODIFY DA	TA – Occupancy	
Inhalation rate	INHALR	8,400	8,400	m ³ /yr	Metabolic Parameter. The mean of NUREG-5512, Vol. 3 PDF used.	NUREG-5512
Mass loading for inhalation	MLINH	0.0001	0.0001	g/m ³	P2 Physical Parameter. RESRAD Default.	NA
Exposure duration	ED	30	30	yr	The standard time that the critical receptor is expected to reside on site.	NA
Indoor dust filtration factor	SHF3	0.4	0.55	unitless	P2 Physical Parameter. The median of the NUREG-6697 PDF used.	NUREG-6697
Fraction of time spent indoors	FIND	0.5	0.66	unitless	Behavioral Parameter. Mean of NUREG-5512 Vol. 3 PDF used.	NUREG-5512
Fraction of time spent outdoors (on-site)	FOTD	0.25	0.12	unitless	Behavioral Parameter. Mean of NUREG-5512 Vol. 3 PDF used.	NUREG-5512
Shape of the contaminated zone: Circular; Non- Circular	FS	Circular	Circular	unitless	P3 Physical Parameter. The modeled shape primarily affects the external pathway.	NA
External gamma shielding factor	SHF1	0.7	0.21	unitless	P2 Physical Parameter. A SF of 0.21 was selected. This is consistent with NUREG/CR- 6697, which recommends an SF of 0.21 for frame homes built on a slab or with a full basement.	NUREG-6697

RESRAD ONSITE	1				INPUT PARAMETER	
Parameter	Code	Default	Value	Units	Justification	Reference
		_	- MC	DIFY DATA	– Ingestion: Dietary	
Fruits, vegetables and grain consumption	DIET(1)	160	112	kg/yr	Behavioral Parameters. Mean of NUREG - 5512 PDFs used.	NUREG - 5512
Leafy vegetable consumption	DIET(2)	14	21	kg/yr	Behavioral Parameters. Mean of NUREG - 5512 PDFs used.	NUREG - 5512
Milk consumption	DIET(3)	92	233	L/yr	Behavioral Parameters. Mean of NUREG - 5512 PDFs used.	NUREG - 5512
Meat and poultry consumption	DIET(4)	63	65	kg/yr	Behavioral Parameters. Mean of NUREG - 5512 PDFs used.	NUREG - 5512
Soil ingestion rate	SOIL	36.5	18.2	g/yr	Behavioral Parameter. Mean of NUREG-5512 Vol. 3 PDF used.	NUREG - 5512
Drinking water intake	DWI	510	460	L/yr	Behavioral Parameter. Mean of NUREG-5512 Vol. 3 PDF used.	NUREG-5512
Contamination fraction of drinking water	FDW	1	1	unitless	All drinking water assumed to be contaminated.	NA
Contamination fraction of household water	FHHW	1	NA	unitless	NA. Radon pathway not active.	NA
Contamination fraction of livestock water	FLW	1	1	unitless	All livestock water assumed to be contaminated.	NA
Contamination fraction of irrigation water	FDW	1	1	unitless	All irrigation water assumed to be contaminated.	NA
Contamination fraction of plant food	FPLANT	-1	-1	unitless	Value of -1 automatically adjusts percentage of contaminated food ingested based on the contaminated site area.	NA
Contamination fraction of Meat	FMEAT	-1	-1	unitless	Value of -1 automatically adjusts percentage of contaminated food ingested based on the contaminated site area.	NA
Contamination fraction of Milk	FMILK	-1	-1	unitless	Value of -1 automatically adjusts percentage of contaminated food ingested based on the contaminated site area.	NA
			MOD	IFY DATA – I	ingestion: Non-Dietary	
Livestock fodder intake for Meat	LFI5	68	68	kg/d	P3 Physical Parameters. RESRAD default used.	NA
Livestock fodder intake for Milk	LFI6	55	55	kg/d	P3 Physical Parameters. RESRAD default used.	NA
Livestock water intake for Meat	LWI5	50	50	L/d	P3 Physical Parameters. RESRAD default used.	NA
Livestock water intake for Milk	LWI6	160	160	L/d	P3 Physical Parameters. RESRAD default used.	NA
Livestock soil intake	LSI	0.5	05	kg/d	P3 Physical Parameters. RESRAD default used.	NA
Mass loading for foliar deposition	MLFD	0.0001	0.0001	g/m ³	P3 Physical Parameter. RESRAD default.	NA
Depth of soil mixing layer	DM	0.15	0.15	m	P2 Physical Parameter. No site-specific data. The most likely value from the PDF recommended in NUREG/CR- 6697 is 0.15 m. See Section 5.3.4.4.	NUREG/CR- 6697
Depth of roots	DROOT	0.9	0.9	m	P1 Physical Parameter. NUREG/CR-6697 states that the root depth for plants that provide the most nutrients typically extend less than 1 meter.	NUREG/CR- 6697
Drinking water fraction from ground water	FGWDW	1	1	unitless	All drinking water assumed to be derived from site ground water.	NA
Household water fraction from ground water	FGWHH	1	NA	unitless	NA. Radon pathway is not selected; hence, this parameter is not applicable.	NA
Livestock fraction from ground water	FGWLW	1	1	unitless	All livestock water assumed to be obtained from site ground water.	NA
Irrigation fraction from ground water	FGWIR	1	1	unitless	All irrigation water assumed to be obtained from site ground water.	NA
				Plant	Factors	
Wet weight crop yield for non-leafy vegetables	YV(1)	0.7	0.56	kg/m ²	P2 Physical Parameter. No site-specific data. The mean of the NUREG/CR-6697 PDF used.	NUREG/CR- 6697
Wet weight crop yield for leafy vegetables	YV(2)	1.5	1.5	kg/m ²	P3 Physical Parameter. RESRAD default used.	NA
Wet weight crop yield for fodder	YV(3)	1.1	1.1	kg/m ²	P3 Physical Parameter. RESRAD default used.	NA

RESRAD ONSITE			INPUT PARAMETER							
Parameter	Code	Default	Value	Units	Justification	Reference				
Growing season for leafy vegetables	TE(2)	0.25	0.25	yr	P3 Physical Parameter. RESRAD default used.	NA				
Growing season for non-leafy vegetables	TE(1)	0.17	0.17	yr	P3 Physical Parameter. RESRAD default used.	NA				
Growing season for fodder	TE(3)	0.08	0.08	yr	P3 Physical Parameter. RESRAD default used.	NA				
Translocation factor for non-leafy vegetables	TIV(1)	0.1	0.1	unitless	P3 Physical Parameter. The RESRAD default value was used.	NA				
Translocation factor for leafy vegetables	TIV(2)	1	1	unitless	P3 Physical Parameters. A value of 1 was assigned assuming the entire plant is consumed.	NA				
Weathering removal constant for vegetation	WLAM	20	33	unitless	P2 Physical Parameter. The median of NUREG/CR-6697 PDF used.	NUREG/CR-6697				
Wet foliar interception fraction for non-leafy vegetables	RWET(1)	0.25	0.25	unitless	P3 Physical Parameter. RESRAD default value used.	NA				
Wet foliar interception fraction for leafy vegetables	RWET(2)	0.25	0.6	unitless	P2 Physical Parameter. Median of NUREG/CR-6697 PDF used.	NUREG/CR-6697				
Wet foliar interception fraction for fodder	RWET(3)	0.25	0.25	unitless	P3 Physical Parameters. RESRAD default value used.	NA				
Dry foliar interception fraction for non-leafy vegetables	RDRY(1)	0.25	0.25	unitless	P3 Physical Parameters. RESRAD default value used.	NA				
Dry foliar interception fraction for leafy vegetables	RDRY(2)	0.25	0.25	unitless	P3 Physical Parameters. RESRAD default value used.	NA				
Dry foliar interception fraction for fodder	RDRY(3)	0.25	0.25	unitless	P3 Physical Parameters. RESRAD default value used.	NA				
	-	-	ľ	MODIFY DA	TA – Storage Time					
Storage time: fruits, non-leafy vegetables, and grain	STOR_T(1)	14	14	D	P3 Physical Parameters. RESRAD default values used.	NA				
Storage time: leafy vegetables	STOR_T(2)	1	1	D	P3 Physical Parameters. RESRAD default values used.	NA				
Storage time: milk	STOR_T(3)	1	1	D	P3 Physical Parameters. RESRAD default values used.	NA				
Storage time: meat and poultry	STOR_T(4)	20	20	D	P3 Physical Parameters. RESRAD default values used.	NA				
Storage time: well water	STOR_T(7)	1	1	D	P3 Physical Parameters. RESRAD default values used.	NA				
Storage time: livestock fodder	STOR_T(9)	45	45	D	P3 Physical Parameters. RESRAD default values used.	NA				

RESRAL	) ONSITE						INPUT PARAME	TER			
Parameter	Code	Default	Value	Units			Justificati	on			Reference
					CHANGE TIT	LES					
Internal dose factor library	NA	NA	FGR-11	NA	Federal Guidance	Report 11 Dose Fa	actors required by N	JRC.			NUREG-1757
External dose factor library	NA	NA	FGR-12	NA	Federal Guidance	Report 12 Dose Fa	actors required by N	JRC.			NUREG-1757
Cut-off ½ life	NA	180	180	days	Cut-off for daught	er products (proge	eny) for in-growth c	alculation.			NA
	_		-	_	SET PATHW	AY					_
External gamma	NA	Active	Active	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Inhalation (w/o radon)	NA	Active	Active	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Plant ingestion	NA	Active	Inactive	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Meat ingestion	NA	Active	Inactive	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Milk ingestion	NA	Active	Inactive	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Aquatic foods	NA	Active	Inactive	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Drinking water	NA	Active	Active	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Soil ingestion	NA	Active	Active	unitless	Site Conceptual M	odel, Industrial W	orker.				NA
Radon NA Active Inactive unitless NUREG-1757, Vol. 2, Section J.4 states that the Radon pathway should be turned off.											NUREG-1757
				MODI	FY DATA – Soil C	Concentrations					
Activity units	NA	pCi	pCi	NA	Standard reporting	units.					NA
Dose units	NA	mrem	mrem	NA	Standard reporting	units.					NA
Basic radiation dose limit	NA	NA	100	mrem/yr	NRC TEDE limit f	for restricted site re	elease.				10 CFR 20.1403
Nuclide concentration	S(i)	NA	1	pCi/g	A unit concentration	on was used as the	input value for eacl	h COC.			NA
	_		_	_	 Transport						_
Unsaturated Zone	NA	1	1	unitless	One UZ was inclu	ded in the CSM.					NA
Time since material placement	TI	0	0	yr	Parameter only ap	plicable when used	d to estimate distrib	ution coefficients			NA
Ground water Concentration	W(i)	NA	NA	pCi/L	Parameter only ap	plicable when used	d to estimate distrib	ution coefficients			NA
Solubility Limit	SOLUBK0(i)	0	0	Mol/L	Parameter only ap	plicable when used	d to estimate distrib	ution coefficients			NA
Leach Rate	RLEACH(i)	0	0	1/yr	Parameter only ap	plicable when used	d to estimate distrib	ution coefficients			NA
Plant/Soil Ratio	NA	Variable	Unchecked	NA	Parameter only ap	plicable when used	d to estimate distrib	ution coefficients			NA
	-	Distril	bution coefficients	s, Kd (Contaminat	ed Zone/ Unsaturat	ed Zone / Saturat	ed Zone)				-
	DCACTC(i)	0	5			Soil Solid/Liquid 1	Partitioning Coaffi	cionts K.S. cm ³	/a		
Carbon	DCACTU1(i)	0	5	cm ³ /g	(Sheppard and Thibault 1990)						Sheppard and Thibault, 1990
	DCACTS(i)	0	5			(~•P]				-	
	DCACTC(i)	4,600	280		Element	Sand	Loam	Clay	Organic		
Cesium	DCACTU1(i)	4,600	280	$cm^{3/g}$	Carbon	5	20	1	70	1	Sheppard and Thibault, 1990
	DCACTS(i)	4,600	280		Cesium	280	4,600	1,900	270		

RESRAI	) ONSITE		INPUT PARAMETER									
Parameter	Code	Default	Value	Units			Justificat	ion			Reference	
					Niobium	160	550	900	2,000			
					Lead	270	16,000	550	22,000			
					Plutonium	550	1,200	5,100	1,900			
					Radium	500	36,000	9,100	2,400			
					Strontium	15	20	110	150			
					Thorium	3,200	3,300	5,800	89,000			
					Uranium	35	15	1,600	410			
	DCACTC(i)	0	160									
Niobium	DCACTU1(i)	0	160	cm ³ /g							Sheppard and Thibault, 1990	
	DCACTS(i)	0	160									
	DCACTC(i)	100	270									
Lead	DCACTU1(i)	100	270	cm ³ /g							Sheppard and Thibault, 1990	
	DCACTS(i)	100	270									
	DCACTC(i)	2,000	550									
Plutonium	DCACTU1(i)	2,000	550	cm ³ /g							Sheppard and Thibault, 1990	
	DCACTS(i)	2,000	550									
	DCACTC(i)	70	500									
Radium	DCACTU1(i)	70	500	$cm^3/g$							Sheppard and Thibault, 1990	
	DCACTS(i)	70	500		_							
	DCACTC(i)	30	15									
Strontium	DCACTU1(i)	30	15	$cm^3/g$							Sheppard and Thibault, 1990	
	DCACTS(i)	30	15		_							
	DCACTC(i)	60,000	3,200									
Thorium	DCACTU1(i)	60,000	3,200	cm ³ /g							Sheppard and Thibault, 1990	
	DCACTS(i)	60,000	3,200		_							
	DCACTC(i)	50	35									
Uranium	DCACTU1(i)	50	35	cm ³ /g							Sheppard and Thibault, 1990	
	DCACTS(i)	50	35									
		1		MOD	DIFY DATA – Calc	ulation Times						
Times for calculation	T(t)	1 to 1,000	1 to 1,000	yr	Standard calculation	n times over 1,00	00-year evaluation p	eriod.			NA	
				MOD	IFY DATA – Conta	minated Zone						
Contaminated zone area	AREA	10,000	1,033 (TR-5) 906.7 (TR-6)	m ²	P2 Physical Param resulting in a depth (2016). The model by 17 ft wide by up 165 CY in CABRE volume that was 40	eter. Assumed all of 0.15 m Trenc area was conserv to 7 ft deep, whi ERA (2016). The oft long by 20 ft	l waste was exhumed th TR-5 waste volun vatively assumed to ich equals 155 m ³ (2 model area was cont wide by up to 6 ft de	d and brought to she estimate is 194 be a rectangular s 03 yd ³ ). Trench T servatively assum cep, which equals	surface and spread over a cubic yards in CABREI oil volume that was46 ft TR-6 waste volume estimated to be a rectangular so $136 \text{ m}^3 (178 \text{ yd}^3)$ ).	an area RA long nate is pil	NA	

RESRAD	ONSITE		INPUT PARAMETER								
Parameter	Code	Default	Value	Units	Justification	Reference					
			0.15 (TD 5)		P2 Physical Parameter. Assumed all waste was spread over 2,023 m ² .						
Contaminated zone thickness	THICK0	2	0.15 (TR-5) 0.15 (TR-6)	m	TR-5 calculated as $155 \text{ m}^3/1,033 \text{ m}^2 = 0.015 \text{ m or } 6$ inches.	NA					
			<u> </u>		TR-6 calculated as 136 m ³ /906.7 m ² = 0.015 m or 6 inches.						
Length parallel to aquifer	LCSPAQ	100	18.1 (TR-5) 17.0 (TR-6)	m	P2 Physical Parameter. Based on a circular source with a radius of 2. Based on a circular source with an area equal to the contaminated zone area above.	NA					
		-		MOD	DIFY DATA – Cover / Hydrology						
Cover depth	COVER0	0	0	m	P2 Physical Parameter. No cover material was assumed.	NA					
Density of contaminated zone	DENSCS	1.5	1.51	g/cm ³	P1 Physical Parameter. Mean Value from NUREG/CR-6697, Attachment C, Table 3.1-1.	NA					
Contaminated zone erosion rate	VCS	0.001	1E-30	m/yr	P2 Physical Parameter. No erosion is assumed since SWMU 11 is located in the remote southwest portion of DPG and lies within a small canyon on the east side of Granite Mountain.	NA					
Contaminated zone total porosity	TPCS	0.4	0.43	unitless	P2 Physical Parameter. Mean value selected for sand in Table 3.2-1 in NUREG/CR-6697.	NUREG/CR-6697					
Contaminated zone field capacity	FCCS	0.2	0.1	unitless	P3 Physical Parameter. Value for sand in Table 2.16.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015					
Contaminated zone hydraulic conductivity	HCCS	10	100	m/yr	P2 Physical Parameter. Value for sand in Table 2.4.1 of the RESRAD Data Collection Handbook (Yu et al. 2015). As noted by Yu et al. 2016, within an anisotropic geological formation, the vertical component of the saturated hydraulic conductivity is usually smaller (by one to two orders of magnitude) than the horizontal component. Therefore, the mean value was reduced by two orders of magnitude for the vertical hydraulic conductivity.	Yu et al. 2015					
Contaminated zone b parameter	BCS	5.3	4.05	m ²	P2 Physical Parameter. The b parameter was selected for sand from Table 2.5.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015					
Humidity in air	HUMID	8	NA	g/m ³	NA. Tritium is not a radionuclide of concern for the site. Humidity input is only required if Tritium is present.	NA					
Evapotranspiration coefficient	EVAPTR	0.5	0.5	unitless	P2 Physical Parameter. RESRAD default used.	NA					
Wind speed	WIND	2	2.68	m/sec	P2 Physical Parameter.	Foster Wheeler 1997					
Precipitation	PRECIP	1	0.1986	m/yr	P2 Physical Parameter. Average annual rainfall (7.82 inches/yr) measured at the Station:(422257) DUGWAY from 1950 to 2006 ( <u>https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?utdugw</u> ).	Desert Research Institute Website					
Irrigation	RI	0.2	0	m/yr	P3 Physical Parameter. No irrigation assumed.						
Runoff coefficient	RUNOFF	0.2	0.4	unitless	P2 Physical Parameter. Site-specific runoff coefficient was calculated using the data provided in NUREG/CR-6697, Att. C, Table 4.2-1 assuming flat cultivated land with intermediate combination of clay and loam.	NUREG/CR-6697					
Watershed area for nearby stream or pond	WAREA	1.00 E+06	NA	m ²	P3 Physical Parameter. Surface water and aquatic food not considered.	NA					
Accuracy for Water / Soil computations	EPS	0.001	0.001	unitless	This is a RESRAD model-related parameter for computational convergence and calculation time.	NA					

RESRAD	ONSITE				INPUT PARAMETER	
Parameter	Code	Default	Value	Units	Justification	Reference
				Μ	ODIFY DATA – Saturated Zone	
Saturated zone density	DENSAQ	1.5	1.51	g/cm ³	P1 Physical Parameter. Mean Value from NUREG/CR-6697, Attachment C, Table 3.1-1.	NA
Saturated zone total porosity	TPSZ	0.4	0.43	unitless	P2 Physical Parameter. Mean PDF value selected for sand in Table 3.2-1 in NUREG/CR-6697.	NUREG/CR-6697
Saturated zone effective porosity	EPSZ	0.2	0.383	unitless	P1 Physical Parameter. Mean of PDF for sand provided in NUREG/CR-6697, Attachment C, Table 3.3-1, was used.	NUREG/CR-6697
Saturated zone field capacity	FCSZ	0.2	0.1	unitless	P3 Physical Parameter. Value for sand in Table 2.16.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Saturated zone hydraulic conductivity	HCSZ	100	5,550	m/yr	P2 Physical Parameter. Value for sand in Table 2.4.2 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Saturated zone hydraulic gradient	HGWT	0.02	0.02	unitless	P2 Physical Parameter. RESRAD default used.	NA
Saturated zone b parameter	BSZ	5.3	4.05	m ²	P2 Physical Parameter. The b parameter was selected for sand from Table 2.5.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Water table drop rate	VWT	0.001	0	m/yr	P3 Physical Parameter. No water table drop due to pumping was assumed.	NA
Well pump intake depth (m below water table)	DWIBWT	10	10	m	P2 Physical Parameter. RESRAD default used.	NA
Model: Non-dispersion (ND) or Mass-Balance (MB)	MODEL	ND	ND	unitless	The area of contamination is approximately 1,000 m ² ; therefore, the non-dispersion model was assumed.	NA
Well pumping rate	UW	250	250	m ³ /yr	P2 Physical Parameter. RESRAD default used.	NA
				N	AODIFY DATA – Unsaturated	
Number of unsaturated strata	NS	1	1	unitless	Based upon site-specific hydrogeology one UZ was modeled.	NA
Unsaturated zone thickness	H(1)	4	18.6	m	P1 Physical Parameter. Depth to groundwater at SWMU-11 is approximately 61 ft bgs based on water- level measurements from MW01.	Parsons 2009
Unsaturated zone density	DENSUZ(1)	1.5	1.51	g/cm ³	P1 Physical Parameter. Mean Value from NUREG/CR-6697, Attachment C, Table 3.1-1.	NA
Unsaturated zone total porosity	TPUZ(1)	0.4	0.43	unitless	P2 Physical Parameter. Mean value selected for sand in Table 3.2-1 in NUREG/CR-6697.	NUREG/CR-6697
Unsaturated zone effective porosity	EPUZ(1)	0.2	0.383	unitless	P1 Physical Parameter. Mean of PDF for sand provided in NUREG/CR-6697, Attachment C, Table 3.3-1, was used.	NUREG/CR-6697
Unsaturated zone field capacity	FCUZ(1)	0.2	0.1	unitless	P3 Physical Parameter. Value for sand in Table 2.16.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015
Unsaturated zone hydraulic conductivity	HCUZ(1)	10	100	m/yr	P2 Physical Parameter. Value for sand in Table 2.4.1 of the RESRAD Data Collection Handbook (Yu et al. 2015). As noted by Yu et al. 2016, within an anisotropic geological formation, the vertical component of the saturated hydraulic conductivity is usually smaller (by one to two orders of magnitude) than the horizontal component. Therefore, the mean value was reduced by two orders of magnitude for the vertical hydraulic conductivity.	Yu et al. 2015
Unsaturated zone b parameter	BUZ(1)	5.3	4.05	m ²	P2 Physical Parameter. The b parameter was selected for sand from Table 2.5.1 of the RESRAD Data Collection Handbook (Yu et al. 2015).	Yu et al. 2015

RESRAD ONSITE		INPUT PARAMETER				
Parameter	Code	Default	Value	Units	Justification	Reference
	MODIFY DATA – Occupancy					
Inhalation rate	INHALR	8,400	8,400	m ³ /yr	Metabolic Parameter. The mean of NUREG-5512, Vol. 3 PDF used.	NUREG-5512
Mass loading for inhalation	MLINH	0.0001	0.0001	g/m ³	P2 Physical Parameter. RESRAD default.	NA
Exposure duration	ED	30	30	yr	The standard time that the critical receptor is expected to reside on site.	NA
Indoor dust filtration factor	SHF3	0.4	0.55	unitless	P2 Physical Parameter. The median of the NUREG-6697 PDF used.	NUREG-6697
Fraction of time spent indoors	FIND	0.5	0.028	unitless	Behavioral Parameter. Industrial worker assumes 8 hr/day for 250 days/yr, of which 1 hr/day is spent indoors.	NA
Fraction of time spent outdoors (on-site)	FOTD	0.25	0.2	unitless	Behavioral Parameter. Industrial worker assumes 8 hr/day for 250 days/yr, of which 7 hr/day is spent outdoors.	NA
Shape of the contaminated zone: Circular; Non-Circular	FS	Circular	Circular	unitless	P3 Physical Parameter. The modeled shape primarily affects the external pathway.	NA
External gamma shielding factor	SHF1	0.7	0.21	unitless	P2 Physical Parameter. A SF of 0.21 was selected. This is consistent with NUREG/CR-6697, which recommends an SF of 0.21 for frame homes built on a slab or with a full basement.	NUREG-6697
	_		_	MOI	DIFY DATA – Ingestion: Dietary	-
Soil ingestion rateSOIL36.518.25g/yrBehavioral Parameter (EPA 1991). 50 mg/day.EPA 1991				EPA 1991		
Drinking water intake	DWI	510	460	L/yr	Behavioral Parameter. Mean of NUREG-5512 Vol. 3 PDF used.	NUREG-5512
Contamination fraction of drinking water	FDW	1	1	unitless	All drinking water assumed to be contaminated.	NA
Contamination fraction of household water	FHHW	1	NA	unitless	NA. Radon pathway not active.	NA
MODIFY DATA – Ingestion: Non-Dietary						
Drinking water fraction from ground water	FGWDW	1	1	unitless	All drinking water assumed to be derived from site ground water.	NA
Household water fraction from ground water	FGWHH	1	NA	unitless	NA. Radon pathway is not selected; hence, this parameter is not applicable.	NA

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1	Appendix B – References
2 3	Cabrera, 2016, Final Report: Area 2 Solid Waste Management Unit (SWMU) 11 Trenches TR-5 and TR-6, Dugway Proving Ground, Dugway, Utah. September 2016.
4	Code of Federal Regulations, Title 10, Part 20.1402, "Standards for Protection Against
5	Radiation–Radiological Criteria for Unrestricted Use."
6	Code of Federal Regulations, Title 10, Part 20.1403, "Standards for Protection Against Radiation–
7	Criteria for License Termination Under Restricted Conditions."
8	Desert Research Institute website: https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?utdugw.
9	EPA 1991. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure
10	Factors," OSWER Directive 9285.6-03, Washington, D.C., March.
11	Federal Guidance Report No. 11: Limiting Values of Radionuclide Intake and Air Concentration and
12	Dose Conversion Factors for Inhalation, Submersion, and Ingestion, EPA-520/1-88-020,
13	U.S. Environmental Protection Agency, September 1988.
14	Federal Guidance Report No. 12: <i>External Exposure to Radionuclides in Air, Water, and Soil</i> , EPA-402-
15	R-93-081, U.S. Environmental Protection Agency, September 1993.
16	Foster Wheeler, 1997, <i>Dugway Proving Ground Closure Plan Module 2: SWMUs 20, 164, 166, and 170,</i>
17	Foster Wheeler Environmental Company, July 1997.
18 19	Parsons, 2009, Final Phase II RCRA Facility Investigation: SWMU 11 Addendum, Dugway Proving Ground, Dugway, UT, August 2009.
20 21	Sheppard, M.I., and D.H. Thibault, 1990, "Default Soil Solid/Liquid Partition Coefficients, KdS, for Four Major Soil Types: A Compendium," <i>Health Physics</i> 59(4):471-82, October 1990.
22	U.S. Nuclear Regulatory Commission, NUREG-1757, "Consolidated Decommissioning Guidance,
23	Characterization, Survey, and Determination of Radiological Criteria," Volume 2, Revision 1,
24	September 2006.
25	U.S. Nuclear Regulatory Commission, NUREG/CR-6697, ANL/EAD/TM-98, "Development of
26	Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes," November 2000.
27	U.S. Nuclear Regulatory Commission, NUREG/CR-5512, SAND99-2148, Volume 3, "Residual
28	Radioactive Contamination from Decommissioning - Parameter Analysis," Draft, October
29	1999.
30	Yu, C., C. Loureiro, JJ. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia, and E. Faillace. Data Collection
31	Handbook to Support Modeling Impacts of Radioactive Material in Soil, ANL/EVS/TM-
32	14/4, Argonne National Laboratory, September 2015.

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34	Appendix C
35	DCGL Sensitivity and Uncertainty Analysis

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## C.1 INTRODUCTION

Sensitivity and uncertainty analyses were conducted on the RESRAD models for the Resident Farmer and Industrial Worker scenarios. The analyses were focused on Ra-226 at TR-5.

## C.2 SENSITIVITY ANALYSIS PARAMETERS

A parameter sensitivity analysis was conducted for the Resident Farmer and Industrial Worker scenarios for Ra-226 at TR-5. Ra-226 was chosen for the sensitivity and uncertainty analysis since it is widely distributed throughout TR-5. Similar parameter sensitivities and uncertainties would be expected for the other COCs for which DCGLs were developed. The parameters considered in the sensitivity analyses were based on those provided in NUREG/CR-6697 and are provided in Tables C-1 and C-2 for the Resident Farmer and Industrial Worker scenarios, respectively.

Parameter Description	Code	Sensitivity Range Factor ^a
Sorption Coefficient (K _d ) of Ra-226 in contaminated zone	DCACTC	10
Sorption Coefficient ( $K_d$ ) of Ra-226 in unsaturated zone 1	DCACTU	10
Sorption Coefficient (K _d ) of Ra-226 in saturated zone	DCACTS	10
Density of contaminated zone	DENSCZ	1.5
Density of unsaturated zone 1	DENSUZ(1)	1.5
Density of saturated zone	DENSAQ	1.5
Total porosity contaminated zone	TPCZ	2
Total porosity of unsaturated zone 1	TPUZ(1)	2
Total porosity of saturated zone	TPSZ	2
Effective porosity of unsaturated zone 1	EPUZ(1)	2
Saturated zone effective porosity	EPSZ	2
Contaminated zone hydraulic conductivity	HCCZ	10
Hydraulic conductivity of unsaturated zone 1	HCUZ(1)	10
Saturated zone hydraulic conductivity	HCSZ	2
Contaminated zone b parameter	BCZ	2
b parameter of unsaturated zone 1	BUZ(1)	2
Saturated zone hydraulic gradient	HGWT	2
Runoff coefficient	RUNOFF	2
Well pumping rate	UW	2
Inhalation rate	INHALR	2
Mass loading for inhalation	MLINH	2
Indoor dust filtration factor	SHF3	1.5
External gamma shielding factor	SHF1	2

Table C-1. Resident farmer scenario sensitivity parameters and ranges considered.

## Table C-1. (continued).

Parameter Description	Code	Sensitivity Range Factor ^a
Fruit, vegetable, and grain consumption ^b	DIET(1)	2
Milk consumption ^b	DIET(3)	1.5
Soil ingestion	SOIL	2
Drinking water intake	DWI	3
Depth of soil mixing layer	DM	2
Depth of roots ^b	DROOT	2
Wet weight crop yield of fruit, grain and non-leafy vegetables ^b	YV(1)	1.5
Weathering removal constant of all vegetation ^b	WLAM	1.2
Indoor time fraction ^b	FIND	1.5
Wind speed	WIND	5
Evapotranspiration coefficient	EVAPTR	2

a. The parameter base value is multiplied by factor to obtain the maximum value and divided by the factor to obtain the minimum value.

Parameter Description	Code	Sensitivity Range Factor ^a
Sorption Coefficient ( $K_d$ ) of Ra-226 in contaminated zone	DCACTC	10
Sorption Coefficient (K _d ) of Ra-226 in unsaturated zone 1	DCACTU	10
Sorption Coefficient (K _d ) of Ra-226 in saturated zone	DCACTS	10
Density of contaminated zone	DENSCZ	1.5
Density of unsaturated zone 1	DENSUZ(1)	1.5
Density of saturated zone	DENSAQ	1.5
Total porosity contaminated zone	TPCZ	2
Total porosity of unsaturated zone 1	TPUZ(1)	2
Total porosity of saturated zone	TPSZ	2
Effective porosity of unsaturated zone 1	EPUZ(1)	2
Saturated zone effective porosity	EPSZ	2
Contaminated zone hydraulic conductivity	HCCZ	10
Hydraulic conductivity of unsaturated zone 1	HCUZ(1)	10
Saturated zone hydraulic conductivity	HCSZ	2
Contaminated zone b parameter	BCZ	2
b parameter of unsaturated zone 1	BUZ(1)	2
Saturated zone hydraulic gradient	HGWT	2

### Table C-2. Industrial worker scenario sensitivity parameters and ranges considered.

Table	C-2. (	continu	ed).
			,

Parameter Description	Code	Sensitivity Range Factor ^a
Runoff coefficient	RUNOFF	2
Well pumping rate	UW	2
Inhalation rate	INHALR	2
Mass loading for inhalation	MLINH	2
External gamma shielding factor	SHF1	2
Soil ingestion	SOIL	2
Drinking water intake	DWI	3
Depth of soil mixing layer	DM	2
Wind speed	WIND	5
Evapotranspiration coefficient	EVAPTR	2

a. The parameter base value is multiplied by factor to obtain the maximum value and divided by the factor to obtain the minimum value.

## C.2.1 Sensitivity Analysis Results – Resident Farmer Scenario

The results of the sensitivity analysis for the Resident Farmer scenario are provided in Figures C-1 through C-36. The doses based on the upper, middle and lower parameter values are provided in each figure, however, in several cases the doses are the same (i.e., parameter is not sensitive). The following parameters were found to have the highest sensitivities in the Resident Farmer scenario:

- 1) Sorption coefficient  $(K_d)$  of the contaminated zone
- 2) Density of the contaminated zone
- 3) Runoff coefficient
- 4) External gamma shielding factor
- 5) Fruit, vegetable and grain consumption rate
- 6) Soil ingestion
- 7) Depth of soil mixing layer
- 8) Depth of roots
- 9) Indoor time fraction
- 10) Evapotranspiration coefficient.



Figure C-1. Sorption coefficient (K_d) in the contaminated zone.



Figure C-2. Sorption coefficient (K_d) in the unsaturated zone.



Figure C-3. Sorption coefficient (K_d) in the saturated zone.


Figure C-4. Density of the contaminated zone.



Figure C-5. Density of the unsaturated zone.



Figure C-6. Density of the saturated zone.



Figure C-7. Total porosity of the contaminated zone.



Figure C-8. Total porosity of the unsaturated zone.



Figure C-9. Total porosity of the saturated zone.



Figure C-10. Effective porosity of the unsaturated zone.



Figure C-11. Effective porosity of the saturated zone.



Figure C-12. Contaminated zone hydraulic conductivity.



Figure C-13. Unsaturated zone hydraulic conductivity.



Figure C-14. Saturated zone hydraulic conductivity.



Figure C-15. Contaminated zone b parameter.



Figure C-16. Unsaturated zone b parameter.



Figure C-17. Saturated zone hydraulic gradient.







Figure C-19. Well pumping rate.



Figure C-20. Inhalation rate.



Figure C-21. Mass loading for inhalation.



Figure C-22. Indoor dust filtration factor.



Figure C-23. External gamma shielding factor.



Figure C-24. Fruit, vegetable and grain consumption.



Figure C-25. Milk Consumption.



Figure C-26. Soil Ingestion.



Figure C-27. Drinking water intake.



Figure C-28. Depth of soil mixing layer.



Figure C-29. Depth of roots.



Figure C-30. Wet weight crop yield for fodder.



Figure C-31. Wet weight crop yield for leafy vegetables.



Figure C-32. Wet weight crop yield for non-leafy vegetables.



Figure C-33. Weathering removal constant for all vegetation.



Figure C-34. Indoor time fraction.



Figure C-35. Wind Speed.



Figure C-36. Evapotranspiration coefficient.

## C.2.1 Sensitivity Analysis Results –Industrial Worker Scenario

The results of the sensitivity analysis for the Industrial Worker scenario are provided in Figures C-37 through C-63. The doses based on the upper, middle and lower parameter values are provided in each figure, however, in several cases the doses are the same (i.e., parameter is not sensitive). The following parameters were found to have the highest sensitivities in the Industrial Worker scenario:

- 1) Sorption coefficient  $(K_d)$  of the contaminated zone
- 2) Density of the contaminated zone
- 3) Runoff coefficient
- 4) External gamma shielding factor
- 5) Soil ingestion
- 6) Depth of soil mixing layer
- 7) Evapotranspiration coefficient.










Figure C-39. Sorption coefficient (K_d) in the saturated zone.



Figure C-40. Density of the contaminated zone.



Figure C-41. Density of the unsaturated zone.



Figure C-42. Density of the saturated zone.







Figure C-44. Total porosity of the unsaturated zone.



Figure C-45. Total porosity of the saturated zone.



Figure C-46. Effective porosity of the unsaturated zone.



Figure C-47. Effective porosity of the saturated zone.







Figure C-49. Unsaturated zone hydraulic conductivity.



Figure C-50. Saturated zone hydraulic conductivity.



Figure C-51. Contaminated zone b parameter.



Figure C-52. Unsaturated zone b parameter.



Figure C-53. Saturated zone hydraulic gradient.



Figure C-54. Runoff Coefficient.



Figure C-55. Well pumping rate.



Figure C-56. Inhalation rate.



Figure C-57. Mass loading for inhalation.



Figure C-58. External gamma shielding factor.







Figure C-60. Drinking water intake.



Figure C-61. Depth of soil mixing layer.



#### Figure C-62. Wind Speed.



Figure C-63. Evapotranspiration coefficient.

## C.3 UNCERTAINTY ANALYSIS

Uncertainty analyses were conducted for the Resident Farmer and Industrial Worker scenarios for the parameters found to be the most sensitive based on the sensitivity analyses conducted in Section C.2.

Two uncertainty analyses were run for each of the Resident Farmer and Industrial Worker scenario consisting of (1) parameter uncertainty based on the lower quartile (25%) and upper quartile (75%) of the sensitive parameters based on the RESRAD-ONSITE parameter distributions provided in NUREG/CR-6697, and (2) parameter uncertainty based on sampling of the full RESRAD-ONSITE parameter distributions provided in NUREG/CR-6697.

The parameter distribution parameter values for the quantile uncertainty analysis are provided in Table C-3.

The parameter distributions used in the full distribution uncertainty analyses are provided in Table C-4.

## C.3.1 Uncertainty Analysis Results

The DCGL results of the uncertainty analyses are summarized in Table C-5. The base case DCGL model results based on the deterministic runs are also shown to provide a comparison to the uncertainty results.

The full parameter distribution uncertainty results, based on the peak-of-the mean dose distribution, are in agreement with the deterministic base case model results. The peak-of-the-mean DCGLs are considered to be appropriate to compare with the deterministic DCGLs because NRC indicates that when using probabilistic dose modeling, the peak-of-the-mean dose distribution should be used for demonstrating compliance with its License Termination Rule in 10 CFR 20, Subpart E (NUREG-1757).

The quantile parameter value uncertainty analyses produced DCGLs that were less than both the deterministic based case model DCGLs and the full parameter distribution uncertainty DCGLs. However, the use of the lower and upper quantiles for the parameter values is considered overly conservative considering the conservatism already built into the conceptual models for the Resident Farmer and Industrial Worker scenarios.

As noted in Section 4.3.3, the Resident Farmer and Industrial Worker scenarios assume that the entire volume of contaminated soil in a trench is exhumed and spread over the ground surface, resulting in a 6-inch contaminated soil layer. This is a conservative assumption based on Appendix J of NUREG-1757, where a dose assessment strategy for buried waste is provided. The use of this strategy simplifies the analysis and provides a conservative estimate of the radionuclide DCGLs.

In addition, several additional conservatisms were incorporated into the Resident Farmer and Industrial Worker scenarios. These conservatisms include the assumption that a Resident Farmer would actually be able to develop a well in the area to provide water for farming (see Section 4.6). The Industrial Worker scenario also includes the conservative assumption that the worker would be present at this remote site with no facilities for 8 hours per day, 250 days per year for 30 years (see Section 4.3.2).

After consideration of the results of the probabilistic uncertainty analyses, and the conservatism built into the deterministic base case scenarios, it was determined that it is appropriate to use the deterministic base case DCGLs, supported by the peak-of-the-mean DCGLs, for the TR-5 and TR-6 DCGLs.

Parameter Description	Code	Quantile Value	Quantile
Sorption coefficient (Kd) of Ra-226 in contaminated zone	DCACTC	8514	Upper (75%)
Density of contaminated zone	DENSCZ	1.675	Upper (75%)
Runoff coefficient	RUNOFF	0.625	Upper (75%)
External gamma shielding factor	SHF1	0.46	Upper (75%)
Fruit, vegetable, and grain consumption ^b	DIET(1)	238	Upper (75%)
Soil ingestion	SOIL	23.6	Upper (75%)
Depth of soil mixing layer	DM	0.15	Lower (25%)
Depth of roots ^b	DROOT	1.225	Lower (25%)
Indoor time fraction ^b	FIND	0.66	Base value no change
Evapotranspiration coefficient	EVAPTR	0.6875	Upper (75%)

#### Table C-3. Parameter values used in the quantile uncertainty analyses.

a.

The quantiles were determined from the RESRAD distributions in NUREG/CR-6697. These parameter distributions were not used in the Industrial Worker scenario quantile uncertainty analysis. b.

Parameter Description	Code	Distribution	Description of Parameter Distribution
Kd of Ra-226 in contaminated zone	DCACTC	Lognormal-n	μ Normal: 8.17 σ Normal: 1.7
Density of contaminated zone	DENSCZ	Truncated normal	μ: 1.52 σ: 0.23 Quantile, Minimum: 0.001 Quantile, Maximum: 0.999
Runoff coefficient	RUNOFF	Uniform	Minimum: 0.1 Maximum: 0.8
External gamma shielding factor	SHF1	Bounded lognormal-n	μ Normal: -1.3 σ Normal: 0.59 Minimum: 0.044 Maximum: 1
Fruit, vegetable, and grain consumption ^b	DIET(1)	Triangular	Minimum: 135 Mode: 178 Maximum: 318
Soil ingestion	SOIL	Triangular	Minimum: 0 Mode: 18.3 Maximum: 36.5
Depth of soil mixing layer	DM	Triangular	Minimum: 0 Mode: 0.15 Maximum: 0.6
Depth of roots ^b	DROOT	Uniform	Minimum: 0.3 Maximum: 4
Indoor time fraction ^b	FIND	Continuous linear	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
Wind speed	WIND	Bounded lognormal-n	μ Normal: 1.445 σ Normal: 0.2419 Minimum: 1.4 Maximum: 13
Evapotranspiration coefficient	EVAPTR	Uniform	Minimum: 0.5 Maximum: 0.75

 Table C-4. Parameter values used in the full parameter distribution uncertainty analyses.

a. All distributions are RESRAD defaults available in NUREG/CR-6697.

b. These parameter distributions were not used in the Industrial Worker scenario uncertainty analysis.

	DCGL (pCi/g)			
Scenario	Base Case	Quantile Uncertainty	Full Distribution Uncertainty	
Resident Farmer	7.4	4.4	7.5	
Industrial Worker	55	51	54	

#### Table C-5. Uncertainty Analysis Results.

## C.4 REFERENCES

- U.S. Nuclear Regulatory Commission, NUREG-1757, "Consolidated Decommissioning Guidance, Characterization, Survey, and Determination of Radiological Criteria," Volume 2, Revision 1, September 2006.
- U.S. Nuclear Regulatory Commission, NUREG/CR-6697, ANL/EAD/TM-98, "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes," November 2000.

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## Appendix B

**Ecological Risk Screening** 

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## **ECOLOGICAL RISK SCREENING FOR TR-5 AND TR-6**

#### INTRODUCTION

An ecological risk screening analysis was conducted for Area 2 of SWMU 11 TR-5 and TR-6 radiological contaminants to confirm ecological receptors are not a driver for remedial actions. Biotic concentration guidelines (BCGs) were derived using the RESRAD-BIOTA computer model (DOE, 2004).

#### **RESRAD-BIOTA DESCRIPTION**

The RESRAD-BIOTA code (DOE, 2004) provides a complete spectrum of biota dose evaluation capabilities, from methods for general screening, to comprehensive receptor-specific dose estimation. The code was designed to be consistent with and provide a tool for implementing the DOE "Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE, 2002).

#### **RESRAD-BIOTA SCREENING ASSUMPTIONS**

Key assumptions used in deriving the BCGs that highlight the conservatism applied in the general screening model of RESRAD-BIOTA are presented below in **Table 1**. Exposure pathways for each of the reference organism types considered in the graded approach are presented below in **Figures 1 and 2**. A summary of the general dose equation and approach used to derive the BCGs is provided below in **Table 2**. The deer mouse (*Peromyscus maniculatus*) was selected as the species for evaluation because it was noted as the predominant rodent species in the area and would be representative of maximum potential exposure.

#### MODIFICATIONS to SCREENING DATA

The only modification to the RESRAD-BIOTA screening data and assumptions was for the area factor, which is a correction factor for exposure and receptor residence time for the selected organism for a finite area of contamination. Due to the limited area of TR-5 and TR-6, this factor was modified for terrestrial animals to 0.2 based on the range of deer mice (Wood et al., 2010). Wood et. al., (2010) present the range of deer mice between 360-5,868 m². Using the minimum deer mice range of 360 m² and the area of TR-5 (i.e., minimum contamination area) of 72.65 m², results in an area factor of 0.2 (i.e., 72.65 m²/360 m² = 0.2)

The area factor for terrestrial plants was maintained at the default value of 1.0.

#### **RESRAD-BIOTA BCGs**

The RESRAD-BIOTA BCGs for terrestrial animal and terrestrial plants are provided below in **Tables 3** and 4, respectively.

#### **COMPARISON OF BCGs to TR-5 and TR-6 SOIL CONCENTRATIONS**

A comparison of the maximum and average soil concentration and also the debris samples from Cabrera (2016) to the terrestrial animal BCGs are provided below in **Table 5**. The terrestrial animal BCGs provided the limiting BCGs.

The only exceedance of the terrestrial animal BCGs was for the maximum soil concentrations of Ra-226 at TR-5. However, it is highly unlikely that the animal would only be exposed to the maximum soil concentration. Therefore, the average soil concentration is considered a better metric of the soil concentration to which the terrestrial animal would be exposed.

Based on the average soil concentrations at TR-5 and TR-6, the BCGs would not be exceeded. This evaluation confirmed that there are no ecological COCs and therefore, remedial action is not required to address ecological exposure pathways.

#### REFERENCES

- Cabrera, 2016, Final Report: Area 2 Solid Waste Management Unit (SWMU) 11 Trenches TR-5 and TR-6, Dugway Proving Ground, Dugway, Utah. September 2016.
- DOE. 2002. DOE STANDARD: A GRADED APPROACH FOR EVALUATING RADIATION DOSES TO AQUATIC AND TERRESTRIAL BIOTA. DOE-STD-1153-2002. U.S. Department of Energy Washington, D.C. 20585.
- DOE. 2004. USER'S GUIDE, VERSION 1: RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation. DOE/EH-0676. United States Department of Energy, Interagency Steering Committee on Radiation Standards. January 2004.
- B.A. Wood, L. Cao, M.D. Dearing. 2010. Deer Mouse (*Peromyscus maniculatus*) Home-Range Size and Fidelity in Sage-Steppe Habitat. Western North American Naturalist, 70(3):345-354 (2010).

# Table 1. Assumptions Regarding Sources, Receptors, and Routes of Exposure Applied in the RESRAD-BIOTA model.

RESKAD-DIOTA mouer	•
Dose Limits	• BCGs were derived for terrestrial plant and terrestrial animal reference organisms. The dose rate limits used to derive the BCGs for each organism type are 1 rad/d, and 0.1 rad/d respectively.
	• While existing effects data support the application of these dose limits to representative individuals within populations of plants and animals, the assumptions and parameters applied in the derivation of the BCGs are based on a maximally exposed individual, representing a conservative approach for screening purposes.
External Sources of Radiation Exposure	• Estimates of the contribution to dose from external radioactive material were made assuming that all of the ionizing radiation was deposited in the organism (i.e., no pass-through and no self-shielding). This is conservative and is tantamount to assuming that the radiosensitive tissues of concern (the reproductive tissues) lie on the surface of a very small organism.
	• For external exposure to contaminated soil, the source was presumed to be infinite in extent. In the case of external exposure to contaminated sediment and water, the source was presumed to be semi-infinite in extent.
	• The source medium to which the organisms are continuously exposed is assumed to contain uniform concentrations of radionuclides.
	• These assumptions provide for appropriately conservative estimates of energy deposition in the organism from external sources of radiation exposure.
Internal Sources of Radiation Exposure	• Estimates of the contribution to dose from internal radioactive material were conservatively made assuming that all of the decay energy is retained in the tissue of the organism, (i.e., 100% absorption).
	• Progeny of radionuclides and their decay chains are also included. This provides an over-estimate of internal exposure, as the lifetime of many of the biota of interest is generally short compared to the time for the build-up of progeny for certain radionuclides.
	• The radionuclides are presumed to be homogeneously distributed in the tissues of the receptor organism. This is unlikely to under-estimate the actual dose to the tissues of concern (i.e., reproductive organs).
	• A radiation weighing factor of 20 for alpha particles is used in calculating the BCGs for all organism types. This is conservative, especially if non- stochastic effects are most important in determining harm to biota. The true value may be a factor of 3 to 4 lower.



Figure 1. Exposure Pathways for Terrestrial Plants in the RESRAD-BIOTA Model.



Figure 2. Exposure Pathways for Terrestrial Animals in the RESRAD-BIOTA Model.
#### Table 2. General Dose Equation and Approach Used to Derive BCGs in RESRAD -BIOTA.

Limiting Concentration	Dose Rate Limit
Limiting Concentration •	(Internal Dose Rate) • (External Dose Rate _{soil/sed.} ) • (External Dose Rate _{water} )

- The limiting concentration in an environmental medium was calculated by first setting a target total dose (e.g., 1 rad/d for terrestrial plants, or 0.1 rad/d for terrestrial animals) and then back-calculating to the medium concentration (i.e., the BCG) necessary to produce the applicable dose from radionuclides in the organism (internal dose), plus the external dose components from radionuclides in the environment (external dose).
- The denominator of the generic equation represents the dose per unit media concentration and may be broken down into the base components of internal and external dose.
- Internal doses originate from radionuclides inside the organism's body. The internal dose is calculated as the product of the internal radionuclide concentration and internal dose conversion factor. External doses originate from radionuclides external to the organism and are calculated as the product of the radionuclide concentration in the environmental medium in which the organism resides and an appropriate dose conversion factor.

Terrestrial Animals			
Nuclide	BCG (pCi/g)	Limiting Organism	
C-14	2.38E+04	Yes	
Cs-137	1.04E+02	Yes	
Po-210	2.17E+04	Yes	
Ra-226	2.53E+02	Yes	
Sr-90	1.13E+02	Yes	
Th-229	3.95E+03	Yes	
Th-230	4.99E+04	Yes	
Th-232	7.60E+03	Yes	
U-234	2.57E+04	Yes	
U-235	1.42E+04	Yes	
U-238	7.90E+03	Yes	

#### Table 3. RESRAD-BIOTA BCGs for Terrestrial Animals.

#### Table 4. RESRAD-BIOTA BCGs for Terrestrial Plants.

Terrestrial Plants			
Nuclide	BCG (pCi/g)	Limiting Organism	
C-14	6.07E+04	No	
Cs-137	2.21E+03	No	
Po-210	1.83E+05	No	
Ra-226	2.88E+02	No	
Sr-90	3.57E+03	No	
Th-229	1.03E+04	No	
Th-230	1.75E+05	No	
Th-232	2.37E+04	No	
U-234	5.16E+04	No	
U-235	2.81E+04	No	
U-238	1.57E+04	No	

	DGG	TR-5 (pCi/g)			TR-6 (p	oCi/g)
Nuclide	BCG (pCi/g)	Soil Max	Soil Avg	Debris	Soil Max	Soil Avg
C-14	2.38E+04	213	12.7		221	22.5
Cs-137	1.04E+02	1.6	0.13		1.22	0.34
Po-210	2.17E+04			3520		
Ra-226	2.53E+02	3040	136.6		2.03	1.77
Sr-90	1.13E+02	19.2	1.2		0.17	0.06
Th-229	3.95E+03			30.6		
Th-230	4.99E+04			0.74		
Th-232	7.60E+03			0.84		
U-234	2.57E+04	6.4	1.5	0.8	2.74	1.61
U-235	1.42E+04	0.13	0.04	0.13	0.29	0.13
U-238	7.90E+03	6.7	1.28	0.81	1.71	1.16

Table 5. Comparison of the BCGs to the TR-5 and TR-6 Soil Concentrations.

# Appendix C

**MicroShield Modeling** 

# **MICROSHEILD MODELING FOR TR-5 AND TR-6 CAPS**

#### INTRODUCTION

The MicroShield computer model (Grove Software, 2006) was used to evaluate the closure cap thickness requirements for SWMU 11 TR-5 and TR-6. The closure cap thickness was based on an allowable dose of 25 mrem/yr for an industrial worker.

## **RADIONUCLIDE INVENTORY**

The maximum radionuclide soil and/or debris concentrations for TR-5 and TR-6 were used in the analyses for conservatism and to ensure that the cap thicknesses were not underestimated. The maximum radionuclide concentrations for TR-6 and TR-5 were obtained from the validated data file from Cabrera (2016). The maximum radionuclide concentrations for TR-5 and TR-5 and TR-6 are provided in Tables 1 and 2, respectively.

Radionuclide	Maximum Soil Concentration (pCi/g)
Cs-137	1.22
Nb-94	0.019
Ra-226	2.03
U-232	3.86
U-234	2.74
U-238	1.71

 Table 1. TR-6 maximum radionuclide soil concentrations.

Table 2	TR-5	maximum	radion	uclide (	soil an	d debris	concentrations
Table 2.	1 N-J	maximum	raulollu	ichue s	son an	u uebris	concentrations.

Radionuclide	Maximum Soil Concentration (pCi/g)	Maximum Debris Concentration (pCi/g)
Cs-137	1.6	
Nb-94	8.9	
Ra-226	3,040	
Pu-242		19.7
Po-210		3,520
Th-229		30.6
Th-230		0.74
U-232	3.91	26.2
U-234	6.4	0.8
U-235	0.13	0.13
U-238	6.7	0.81

# **CLOSURE CAP AND SOIL COMPOSITION**

The soil/cap composition for use in MicroShield was based on a silty soil used in the development of the external dose conversion factors developed in EPA's Federal Guidance Report 12 (EPA, 1993). This soil was assumed to have a density of 1.6 g/cm³ (EPA, 1993). The soil composition is provided in Table 3.

Element	Mass Fraction
Н	0.021
С	0.016
0	0.577
Al	0.050
Si	0.271
K	0.013
Са	0.041
Fe	0.011
Total	1.000

Table 3. Soil Composition of a silty sand (EPA, 1993).

### MICROSHIELD INPUT PARAMETERS

The MicroShield input parameter values for TR-5 and TR-6 are provided in Table 4

Parameter	TR-5 Value	TR-6 Value
Trench Length (m)	14.02	12.19
Trench Width (m)	5.18	6.096
Trench Depth (m)	2.13	1.83
Dose Point (m)	1 m above ground surface	1 m above ground surface
Radionuclide Inventory	See Table 2	See Table 1
Soil/Cap Composition	See Table 3	See Table 3
Buildup Material	Based on air gap between ground surface and dose point	Based on air gap between ground surface and dose point

Table 4. MicroShield Input Parameter Values.

### MICROSHIELD RESULTS

The TR-6 cap exposure rates, based on the maximum soil concentrations, are provided in Table 5 for various decay/ingrowth times. The maximum soil concentrations were assumed to be homogenous throughout the 12.19 m (40 ft) by 6.096 (20 ft) by 1.83 m (6 ft) trench.

Decay Time (yr)	Exposure Rate (mR/hr)
0	6.66E-04
1	5.59E-03
5	8.50E-03
10	8.98E-03
15	8.81E-03
50	7.09E-03
100	5.50E-03
500	2.73E-03
1,000	2.17E-03

Table 5. TR-6 no cap exposure rates for different source decay times.

The maximum exposure rate occurs at 10 years of decay/ingrowth for the maximum soil concentrations at TR-6, with an exposure rate of 8.98E-03 mR/hr. Based on an allowable dose of 25 mrem/yr, this exposure rate results in an allowable exposure time of 2,783 hours per year (i.e., conservatively assuming that 1 mR equals 1 mrem).

allowable hours =  $\frac{25 \text{ mrem/yr}}{8.98E - 03 \text{ mR/hr}} = 2783 \text{ hr/yr}$ 

Therefore, for an industrial worker, no cap is required at TR-6 for exposure durations of 2,783 hours per year or less.

The TR-5 cap exposure rates, based on the maximum soil and/or debris concentrations, are provided in Table 6 for various decay/ingrowth times. The maximum soil concentrations were assumed to be homogenous throughout the 14.02 m (46 ft) by 5.18 m (17 ft) by 2.13 m (7 ft) trench.

Decay Time (yr)	Exposure Rate (mR/hr)
0	2.732E-02
1	4.712
5	4.724
10	4.717
25	4.683
50	4.626
100	4.518
500	3.788
1,000	3.052

Table 6. TR-5 no cap exposure rates for different source decay times.

The maximum exposure rate occurs at 5 years of decay/ingrowth for the maximum soil/debris concentrations at TR-5, with an exposure rate of 4.724 mR/hr. Based on an allowable dose of 25 mrem/yr, this exposure rate results in an allowable exposure time of 5.3 hours/yr (i.e., conservatively assuming that 1 mR equals 1 mrem).

allowable hours =  $\frac{25 \text{ mrem/yr}}{4.724 \text{ mR/hr}}$  = 5.3 hr/yr

Therefore, for an industrial worker, a cap would be required for exposure durations greater than 5.3 hours per year.

The allowable worker hours for various cap thicknesses was evaluated in MicroShield based on the maximum soil/debris soil concentrations at the maximum decay/ingrowth time of 5 years. The results of the cap thickness evaluation are provided in Table 7 and Figure 1.

	Allowable Worker Exposure Duration
Cap Thickness	(hr/yr)
0.0 m (0.0 ft)	5.3
0.1524 m (0.5 ft)	22.3
0.3048 m (1.0 ft)	87.7
0.4572 m (1.5 ft)	316.9
0.6096 m (2.0 ft)	1,078.5
0.7620 m (2.5 ft)	3,523.6
0.9144 m (3.0 ft)	11,210.8





#### REFERENCES

- Cabrera, 2016, Final Report: Area 2 Solid Waste Management Unit (SWMU) 11 Trenches TR-5 and TR-6, Dugway Proving Ground, Dugway, Utah. September 2016.
- EPA, 1993, *Federal Guidance Report No. 12: External Exposure to Radionuclides in Air, Water, and Soil,* EPA-402-R-93-081. Keith F. Eckerman and Jeffrey C. Ryman. September 1993.
- Grove Software, 2006, *MicroShield User's Manual, Version 7*. Grove Software, Inc., Lynchburg, Virginia. October 2006.

# Appendix D

# **Exposure Rate Reduction Modeling**

# GROUT STABILIZATION EXPOSURE RATE REDUCTION FOR TR-5 AND TR-6

## INTRODUCTION

The MicroShield computer model (Grove Software 2006) was used to evaluate the exposure rate reductions for SWMU 11 TR-5 and TR-6 due to in-situ grout stabilization of the waste.

### **RADIONUCLIDE INVENTORY**

The maximum radionuclide soil and/or debris concentrations for TR-5 and TR-6 were used in the analyses. The maximum radionuclide concentrations for TR-6 and TR-5 were obtained from the validated data file from Cabrera (2016). The maximum radionuclide concentrations for TR-5 and TR-6 are provided in Table 1 and 2, respectively.

Radionuclide	Maximum Soil Concentration (pCi/g)
Cs-137	1.22
Nb-94	0.019
Ra-226	2.03
U-232	3.86
U-234	2.74
U-238	1.71

 Table 1. TR-6 maximum radionuclide soil concentrations.

Radionuclide	Maximum Soil Concentration (pCi/g)	Maximum Debris Concentration (pCi/g)
Cs-137	1.6	
Nb-94	8.9	
Ra-226	3,040	
Pu-242		19.7
Po-210		3,520
Th-229		30.6
Th-230		0.74
U-232	3.91	26.2
U-234	6.4	0.8
U-235	0.13	0.13
U-238	6.7	0.81

### SOIL AND CONCRETE COMPOSITION

The soil composition for use in MicroShield was based on a silty soil used in the development of the external dose conversion factors developed in EPA's Federal Guidance Report 12 (EPA 1993). This soil was assumed to have a density of 1.6 g/cm³ (EPA 1993). The soil composition is provided in Table 3.

The grout was represented by the National Bureau of Standards (NBS) concrete composition that is provided with the MicroShield model. The concrete has a density of 2.35 g/cm³ and the composition is provided in Table 4.

Element	Mass Fraction
Н	0.021
С	0.016
0	0.577
Al	0.050
Si	0.271
К	0.013
Са	0.041
Fe	0.011
Total	1.000

Table 3. Soil composition of a silty sand (EPA 1993).

|--|

Element	Mass Fraction
Н	0.0056
0	0.4983
Na	0.0171
Mg	0.0024
Al	0.0456
Si	0.3158
S	0.0012
К	0.0192
Са	0.0826
Fe	0.0122
Total	1.000

### MICROSHIELD INPUT PARAMETERS

The MicroShield input parameter values for TR-5 and TR-6 are provided in Table 5.

Parameter	TR-5 Value	TR-6 Value				
Trench Length (m)	14.02	12.19				
Trench Width (m)	5.18	6.096				
Trench Depth (m)	2.13	1.83				
Dose Point (m)	1 m above ground surface	1 m above ground surface				
Radionuclide Inventory	See Table 2	See Table 1				
Soil Composition	See Table 3	See Table 3				
Concrete Composition	See Table 4	See Table 4				
Buildup Material	Based on air gap between ground surface and dose point	Based on air gap between ground surface and dose point				

 Table 5. MicroShield Input Parameter Values.

## MICROSHIELD RESULTS

The exposure rate reduction from the in-situ grouting of waste at TR-5 and TR-6 are presented in Table 6. The exposure rate due to in-situ grouting of the waste results in an exposure rate reduction of 30%.

Table 6. Ex	posure rate	reduction	for in-	situ gro	uting of	the waste a	at TR-5	and TR-6.
				<b>-</b>				

	Exposure R		
Trench	Soil	Concrete	<b>Exposure Reduction</b>
TR-5	4.724	3.303	0.30
TR-6	8.984E-03	6.265E-03	0.30

# REFERENCES

- Cabrera, 2016. Final Report: Area 2 Solid Waste Management Unit (SWMU) 11 Trenches TR-5 and TR-6, Dugway Proving Ground, Dugway, Utah. September 2016.
- EPA. 1993. Federal Guidance Report No. 12: External Exposure to Radionuclides in Air, Water, and Soil. EPA-402-R-93-081. Keith F. Eckerman and Jeffrey C. Ryman. September 1993.
- Grove Software. 2006. MicroShield User's Manual, Version 7. Grove Software Inc. Lynchburg, VA. October 2006.

# Appendix E

**Cost Estimate Evaluation** 

# DUGWAY PROVING GROUND BASIS OF COST ESTIMATES

## November 2019

RACER® provides users with the ability to document estimates at every level of the estimating hierarchy. This capability has been included in the system so that the rationale for estimates can be documented and understood by others and reconstructed later.

#### **Remedial Alternative 2- Land Use Controls**

- Institutional Controls
  - Site use controls
  - Remedial Design
  - Land Use Control Implementation Plan (LUCIP)
  - LUCIP Meetings (2)
  - Access Control Signs (4)
  - $\circ$  Annual Inspection.
- Install Fencing
  - Fencing around both sites
  - Fencing around each site individually.

#### **Remedial Alternative 3- Containment & LUCs**

- Institutional Controls
  - Site use controls
  - Remedial Design
  - o LUCIP
  - LUCIP Meetings (2)
  - Access Control Signs (4)
  - Annual Inspection.
- Install Fencing
  - Fencing around both sites
  - Fencing around each site individually.
- RCRA Hazardous Waste Cap- geosynthetic clay liner (GCL) TR-5 and TR-6
  - Based on Microshield, protective cover of 3 ft
  - Total area of 120 ft  $\times$  70 ft (8,400 ft² to cover both trenches individually)
  - 40-mil HDPE geomembrane
  - 36-inch protective cover.

#### Remedial Alternative 4- Excavation, Off-Site Disposal, and Backfilling (complete after 2 years)

- Documentation, planning, and meetings.
- Excavation
  - Excavate a total of 1,000 CY from both trenches combined. Excavate to a depth of 7 ft bgs.
  - Set up temporary containment area for storage of excavated material
  - Post-excavation confirmation sampling for radionuclides
  - Backfill with certified clean fill
  - Restore surface with native vegetation.

• Dispose of 1,000 CY of low-level waste (LLW) at Energy Solutions- Clive facility as bulk material.

### Remedial Alternative 5- Excavation, Sorting, Screening, and Off-Site Disposal (complete after 2 years)

- Documentation, planning, and meetings.
- Excavation
  - Excavate a total of 1,000 CY from both trenches combined. Excavate to a depth of 7 ft bgs.
  - $\circ$  Set up temporary containment area for storage of excavated material
  - Post-excavation confirmation sampling for radionuclides
  - o Backfill with certified clean fill
  - Restore surface with native vegetation.
- On-Site Radiological Screening
  - Mobilize and demobilize soil screening equipment
  - Pretreat the soils by screening and tilling excavated material
  - Process 1,000 CY
  - Assume 20% contamination level.
- Dispose of 200 CY of LLW at Energy Solutions- Clive facility as bulk material.

#### **Remedial Alternative 6- Soil Stabilization**

- Institutional Controls
  - Site use controls
  - o LUCIP
  - o LUCIP Meetings (2)
  - Access Control Signs (4)
  - Periodic Inspection and maintenance.
- Install Fencing
  - Fencing around both sites
  - Fencing around each site individually.
- In-Situ Grouting (Portland cement or acrylamide)
  - $\circ$  Grout injected under pressure across surface area of 1,782 ft²
  - Injected to a depth of 10 ft bgs
  - Injection radius of influence 6 ft in diameter
  - Pilot test and geotechnical testing.

Timeframe: 30 years				
Alternatives	Total Cost	Capital Costs	Total O&M and Periodic Costs	Present Worth Value
Alternative 1 – No Action	\$0	\$0	\$0	\$0
Alternative 2 - LUCs	\$167,241	\$146,075	\$19,270	\$160,547
Alternative 3 - Containment and LUCs	\$383,000	\$156,000	\$116,000	\$383,000
Alternative 4 - Excavate, Dispose	\$592,757	\$592,757	\$0	\$592,757
Alternative 5 - Excavate, Screen, Dispose	\$1,439,237	\$1,439,237	\$0	\$1,439,237
Alternative 6 - Soil Stabilization	\$487,000	\$454,000	\$29,000	\$481,000

			_	Folder A	ssembly Lev	el Data Report								
Level 1 Name Leve	el 1 ID Level 2 Name Level 2	ID Phase Name	Tech. Key	Technology Name	Assembly No	o. Assembly Description	Qty UOM N	<b>A</b> aterials	Labor Ed	uipment Su	ibBid E	xtended Cost	Cost Override Dup	ications
Dugway Proving Ground, DPG	Dugway Proving Ground DPG	Containment	1	Canning	17030423	Unclassified Fill, 6" Lifts, Off-Site, Includes Delivery, Spreading, and Compaction	1183.72 CY	20.59	1.13	0.89	0.01	26 776 73 F		
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	1	Capping	18050301	Loam or topsoil, imported topsoil, 6" deep, furnish and place	197.29 LCY	30.25	6.00	1.89	0.00	7.524.31 F	ALSE FALS	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	1	Capping	18050402	Seeding, Vegetative Cover	0.2 ACR	3,490.96	506.50	223.00	0.00	844.09 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	1	Capping	33080513	Drainage Netting, Geotextile Fabric Heat-bonded 2 Sides	9375.08 SF	0.68	0.09	0.01	0.00	7,377.27 F	ALSE FALS	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	1	Capping	33080520	Bentonite, rolls, with geotextile fabric both sides, 3/8" thick	9375.08 SF	0.97	0.39	0.03	0.00	13,031.59 F	ALSE FALS	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	1 Total	Capping	33080571	40 Mil Polymeric Liner, High-density Polyethylene	9375.08 SF	0.54	U.24	0.02	0.00	7,523.16 F	ALSE FAL	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	18010412	Construction Signs	96 SF	27.50	0.00	0.00	0.00	2,640.00 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33010202	Per Diem (per person)	2 DAY	0.00	0.00	0.00	183.00	366.00 T	RUE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33010202	Per Diem (per person)	4 DAY	0.00	0.00	0.00	183.00	732.00 T	RUE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33022037	Overnight Delivery, 8 oz Letter Overnight delivery convice, 1 lb nackana	10 EA	0.00	0.00	0.00	29.10	290.95 F	ALSE FALS	E IRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33040671	Portable GPS Set with Manning 5 cm Accuracy	1 MO	5 769 51	0.00	0.00	0.00	5 769 51 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220102	Project Manager	40 HR	0.00	76.68	0.00	0.00	3,067.24 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220102	Project Manager	40 HR	0.00	76.68	0.00	0.00	3,067.24 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220102	Project Manager	30 HR	0.00	76.68	0.00	0.00	2,300.43 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220102	Project Manager	12 HR	0.00	93.51	0.00	0.00	1,122.16 F	ALSE FALS	
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220105	Project Engineer	60 HR	0.00	79.28	0.00	0.00	4 756 83 F	ALSE FAL	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220105	Project Engineer	40 HR	0.00	65.01	0.00	0.00	2,600.40 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220106	Staff Engineer	80 HR	0.00	66.96	0.00	0.00	5,356.56 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220106	Staff Engineer	60 HR	0.00	81.65	0.00	0.00	4,899.29 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220110	QA/QC Officer	14 HR	0.00	52.48	0.00	0.00	734.73 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220110	Word Processing/Clerical		0.00	52.48 35.96	0.00	0.00	092.18 F	ALSE FAL	
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220114	Word Processing/Clerical	32 HR	0.00	35.96	0.00	0.00	1.150.69 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220114	Word Processing/Clerical	40 HR	0.00	43.85	0.00	0.00	1,754.10 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220114	Word Processing/Clerical	1 HR	0.00	43.85	0.00	0.00	43.85 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220115	Draftsman/CADD	120 HR	0.00	41.91	0.00	0.00	5,029.20 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220115	Draftsman/CADD	40 HR 16 UD	0.00	41.91	0.00	0.00	1,070.40 F	ALSE FALS	
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220115	Health and Safety Officer		0.00	68.60	0.00	0.00	68 60 F	ALSE FAL	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220213	Surveying - 3-man Crew	4 DAY	0.00	1,223.29	14.78	0.00	4,952.29 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33220503	Attorney, Partner, Real Estate	30 HR	0.00	153.14	0.00	0.00	4,594.26 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33240101	Other Direct Costs	1 LS	492.06	0.00	0.00	0.00	492.06 T	RUE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33240101	Other Direct Costs	1 LS	30.87	0.00	0.00	0.00	30.87 T	RUE FALS	E TRUE
Dugway Proving Ground DPG Dugway Proving Ground DPG	Dugway Proving Ground DPG Dugway Proving Ground DPG	Containment	14	ADMINISTRATIVE LAND USE CONTROLS	33240101	Other Direct Costs Other Direct Costs	1 L5 1 IS	174.22	0.00	0.00	0.00	174.22 T 643.73 T	RUE FAL	
Eaginary Freeining Creating Dire	Bugnay Honing Cround Brid	Containment	14 Total		00210101		1 20	010.10	0.00	0.00	0.00	65,001.36	NOL TAL	e moe
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	5	Fencing	18040105	Boundary Fence, 5' Galvanized	620 LF	11.55	7.90	2.32	0.00	13,496.78 F	ALSE FALS	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	5 E Tatal	Fencing	18040501	Hazardous Waste Signing	4 EA	137.50	23.89	5.25	0.00	666.56 F	ALSE FALS	E FALSE
Duaway Proving Ground, DPG	Duaway Proving Ground DPG	11108	o Iotal	ADMINISTRATIVE LAND LISE CONTROLS	18010412	Construction Signs	70 SE	27.50	0.00	0.00	0.00	14,163.34 1 990 00 F		
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33010104	Sample collection vehicle mileage charge car or van	100 MI	0.00	0.00	0.00	0.30	29.70 F	ALSE FALS	E FALSE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33010202	Per Diem (per person)	4 DAY	0.00	0.00	0.00	183.00	732.00 T	RUE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33022037	Overnight Delivery, 8 oz Letter	10 EA	0.00	0.00	0.00	29.10	290.95 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33040671	Portable GPS Set with Mapping, 5 cm Accuracy	1 MO	5,769.51	0.00	0.00	0.00	5,769.51 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220102	Project Manager Braiget Monager	40 HR	0.00	76.68	0.00	0.00	3,067.24 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220102	Project Manager Project Manager	43 HR 30 HR	0.00	76.68	0.00	0.00	2 300 43 F	ALSE FAL	
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220105	Project Engineer	34 HR	0.00	65.01	0.00	0.00	2,210,34 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220105	Project Engineer	40 HR	0.00	65.01	0.00	0.00	2,600.40 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220105	Project Engineer	60 HR	0.00	65.01	0.00	0.00	3,900.60 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220106	Staff Engineer	80 HR	0.00	66.96	0.00	0.00	5,356.56 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220100	Stan Engineer	50 HR 14 HR	0.00	66.96 52.48	0.00	0.00	4,017.42 F	ALSE FAL	
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220110	QA/QC Officer	17 HR	0.00	52.40	0.00	0.00	892 18 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220114	Word Processing/Clerical	80 HR	0.00	35.96	0.00	0.00	2,876.72 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220114	Word Processing/Clerical	32 HR	0.00	35.96	0.00	0.00	1,150.69 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220114	Word Processing/Clerical	40 HR	0.00	35.96	0.00	0.00	1,438.36 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220115	Draftsman/CADD Draftsman/CADD	16 HR 190 HD	0.00	41.91	0.00	0.00	670.56 F	ALSE FALS	
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220115	Draftsman/CADD Draftsman/CADD	40 HR	0.00	41.91	0.00	0.00	0,029.20 F	ALSE FAL	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220213	Surveying - 3-man Crew	4 DAY	0.00	1,223.29	14.78	0.00	4,952.29 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33220503	Attorney, Partner, Real Estate	30 HR	0.00	153.14	0.00	0.00	4,594.26 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33240101	Other Direct Costs	1 LS	183.22	0.00	0.00	0.00	183.22 T	RUE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	LUCs	6	ADMINISTRATIVE LAND USE CONTROLS	33240101	Other Direct Costs	1 LS	470.01	0.00	0.00	0.00	470.01 T	RUE FALS	E TRUE
Dugway Froving Ground, DPG	Dugway Froving Ground DPG	LUUS	6 Total	ADMINISTRATIVE LAND USE CONTROLS	33240101		I LS	014:43	0.00	0.00	0.00	60,835,49	NUE FAL:	IRUE
		Excavation and Off-sit	ie i i i i i i i i i i i i i i i i i i											
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal	7	Excavation	17020416	12 CY Dump Truck Haul/Hour	169 HR	0.00	67.62	40.03	0.00	18,193.22 F	ALSE FALS	E TRUE
		Excavation and Off-sit	ie _			Excavate and load, bank measure, medium material, 2 C.Y. bucket, hydraulic								
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal Everyotion and Off cit	7	Excavation	17030277	excavator Upplessified Fill R*Lifts, Off Site Ippludes Delivery, Spreading, and	3072 BCY	0.00	1.10	0.58	0.00	5,170.18 F	ALSE FALS	E TRUE
Dugway Proving Ground, DPG	Duraway Proving Ground DPG	Disnosal	.e 7	Excavation	17030423	Compaction	3532.63 CY	20.59	1:13	0.89	0.01	79.911.02 F	ALSE FALS	E TRUE
Eaginary Flowing Orbania Dr O	Bugway i towing orbuind bi o	Excavation and Off-sit	ie	Excaration	11000420	Compaction	0002.00 01	20.00	1.10	0.00	0.01	10,011.021		E INGE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal Excavation and Off-sit	7 'e	Excavation	18050402	Seeding, Vegetative Cover	0.34 ACR	3,490.96	506.50	223.00	0.00	1,434.96 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal Excavation and Off sit	7	Excavation	33020401	Disposable Materials per Sample Testing, rad applytical vegetation/sediment/spill gas flow proportional counting	11 EA	8.55	0.00	0.00	0.00	94.02 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal	7	Excavation	33022336	gross beta-total	3. 5 EA	0.00	0.00	0.00	69.54	347.69 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Excavation and Off-sit Disposal	е 7	Excavation	33022351	Testing, rad analytical vegetation/sediment/soil, liquid scintillation, tritium	5 EA	0.00	0.00	0.00	75.33	376.67 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Excavation and Off-sit Disposal	ie 7	Excavation	33220102	Project Manager	5 HR	0.00	93.51	0.00	0.00	467.57 F	ALSE FALS	E TRUE
Dunway Proving Ground, DPG	Dunway Proving Ground DPG	Excavation and Off-sit	те 7	Excavation	33220108	Project Scientist	5 HR	0.00	86.32	0.00	0.00	431.62	ALSE FALS	E TRUE
Dugway Proving Orbund DPO	Dugway Hoving Orbund DFO	Excavation and Off-sit	ie 7	Evenuetion	00220100		4 UB	0.00	64.00	0.00	0.00	401.02		
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Lisposal Excavation and Off-sit	:e _	Excavation	33220110		1 HR	0.00	64.00	0.00	0.00	64.00 F	ALSE FALS	E IRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal Excavation and Off-sit	7 :e	Excavation	33220112	Field Technician	1 HR	0.00	44.52	0.00	0.00	44.52 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal Excavation and Off-sit	7 :e	Excavation	33220114	Word Processing/Clerical	1 HR	0.00	43.85	0.00	0.00	43.85 F	ALSE FALS	E TRUE
Dugway Proving Ground DPG	Dugway Proving Ground DPG	Disposal	7 7 Total	Excavation	33220115	Draftsman/CADD	1 HR	0.00	51,11	0.00	0.00	51.11 F	ALSE FALS	E TRUE

Folder Assembly Level Data Report																	
Level 1 Name	Level 1 ID	Level 2 Name	Level 2 ID	Phase Name	Tech. Key	Technology Name	Assembly No	Assembly Description	Qty	UOM N	laterials	Labor E	quipment	SubBid E	Extended Cost Cost Over	ride Duplicatio	ns
Dugway Proving Ground	H DPG	Dugway Proving Groun	nd DPG	Excavation and Off-site Disposal	8	Off-site Transportation and Waste Disposal	33171010	Radioactive Waste Disposal, Energy Solutions, UT, LLRW, Bulk	1000	CY	0.00	0.00	0.00	346.50	346,500.01 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation and Off-site Disposal	8	Off-site Transportation and Waste Disposal	33190102	Bulk Solid Waste Loading Into Disposal Vehicle or Bulk Disposal Container	1000	BCY	1.14	1.27	0.41	0.00	2,825.39 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation and Off-site Disposal	8	Off-site Transportation and Waste Disposal	33190205	Transport Bulk Solid Hazardous Waste, Maximum 20 CY (per Mile)	4250	MI	0.00	0.00	0.00	2.04	8,648.75 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Disposal Excavation and Off site	8	Off-site Transportation and Waste Disposal	33190317	Waste Stream Evaluation Fee, Not Including 50% Rebate on 1st Shipment	1	EA	0.00	0.00	0.00	56.71	56.71 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Disposal	8 8 Total	Off-site Transportation and Waste Disposal	33190807	32 Ft. Dump Truck, 6 Mil Liner, disposable	50	EA	30.91	0.00	0.00	0.00	1,545.50 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	17020416	12 CY Dump Truck Haul/Hour	84	HR	0.00	67.62	40.03	0.00	9.042.78 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	17030277	Excavate and load, bank measure, medium material, 2 C.Y. bucket, hydraulic excavator	2302	BCY	0.00	1.10	0.58	0.00	3,874.27 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	17030423	Unclassified Fill, 6* Lifts, Off-Site, Includes Delivery, Spreading, and Compaction	1747.19	CY	20.59	1.13	0.89	0.01	39,522.89 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	18050402	Seeding, Vegetative Cover	0,19	ACR	3,490.96	506.50	223.00	0.00	801.89 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	33020401	Disposable Materials per Sample	11	EA	8.55	0.00	0.00	0.00	94.02 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	33022336	Testing, rad analytical vegetation/sediment/soil, gas flow proportional counting, gross beta-total	5	EA	0.00	0.00	0.00	69.54	347.69 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	9	Excavation	33022351	Testing, rad analytical vegetation/sediment/soil, liquid scintillation, tritium	5	EA	0.00	0.00	0.00	75.33	376.67 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	excavation, onsite screening, disposal	9	Excavation	33220102	Project Manager	5	HR	0.00	93.51	0.00	0.00	467.57 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal	9	Excavation	33220108	Project Scientist	5	HR	0.00	86.32	0.00	0.00	431.62 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal Excavation, onsite	9	Excavation	33220110	QA/QC Officer	1	HR	0.00	64.00	0.00	0.00	64.00 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal Excavation onsite	9	Excavation	33220112	Field Technician	1	HR	0.00	44.52	0.00	0.00	44.52 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal Excavation, onsite	9	Excavation	33220114	Word Processing/Clerical	1	HR	0.00	43.85	0.00	0.00	43.85 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal	9 9 Total	Excavation	33220115	Draftsman/CADD	1	HR	0.00	51.11	0.00	0.00	51.11 FALSE 55,162.88	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	10	Off-site Transportation and Waste Disposal	33171010	Radioactive Waste Disposal, Energy Solutions, UT, LLRW, Bulk	200	CY	0.00	0.00	0.00	346.50	69,300.00 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	10	Off-site Transportation and Waste Disposal	33190102	Bulk Solid Waste Loading Into Disposal Vehicle or Bulk Disposal Container	200	BCY	1.14	1.27	0.41	0.00	565.08 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	10	Off-site Transportation and Waste Disposal	33190205	Transport Bulk Solid Hazardous Waste, Maximum 20 CY (per Mile)	850	MI	0.00	0.00	0.00	2.04	1,729.75 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	10	Off-site Transportation and Waste Disposal	33190317	Waste Stream Evaluation Fee, Not Including 50% Rebate on 1st Shipment	Ĩ	EA	0.00	0.00	0.00	56.71	56.71 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal	10 10 Tetal	Off-site Transportation and Waste Disposal	33190807	32 Ft. Dump Truck, 6 Mil Liner, disposable	10	EA	30.91	0.00	0.00	0.00	309 10 FALSE	FALSE	TRUE
Dugway Proving Groups		Dudway Proving Group	nd DPG	Excavation, onsite	10 10tai	Low Level Rad Soil Treatment	17030222	928-2.0.CY. Wheel Loader	77	HR	0.00	79.49	43.81	0.00	9 027 84 FALSE	FAL SE	FALSE
Dugway Proving Ground		Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	17030347	Standby, 926, 2.0 CY Wheel Loader	44	HR	0.00	0.00	43.81	0.00	1.927.77 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180401	Mobilize/Demobilize Radiological Screening System	6000	MI	0.00	1.69	8.46	0.00	60.895.46 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180402	Assemble/Shakedown Radiological Screening System	1	EA	0.00 9	5,668.71	0.00	0.00	95,668.71 FALSE	FALSE	FALSE
Dugway Proving Ground	H DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180403	Disassemble/Decontaminate Radiological Screening System	1	EA	0.00 14	0,223.17	0.00	0.00	, 140,223.17 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180404	13 Tons per Hour Radiological Screening System - Monthly Rental	2	мо	0.00	0.00	0.00 1	37,500.00	275,000.01 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180405	Operational Labor - 13 Tons per Hour Radiological Screening System	97	HR	0.00	176.24	0.00	0.00	17,095.42 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180406	Soil Conditioning Charges	1000	TON	0.00	11.01	0.00	0.00	11,013.41 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180407	Maintenance/Spare Parts - 13 Tons per Hour Radiological Screening System	1000	TON	0.00	7.34	0.00	0.00	7,337.81 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Excavation, onsite screening, disposal	12	Low Level Rad Soil Treatment	33180901	Radioactive Waste Disposal Fee	200	CY	0.00	0.00	0.00	1,767.15	353,430.01 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	screening, disposal	12	Low Level Rad Soil Treatment	33420101	Electrical Charge	15384.6	KWH	0.15	0.00	0.00	0.00	2,369.23 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33150405	Portland Cement Type I (Bulk)	133.65	TON	113.30	0.00	0.00	0.00	15,142.55 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33150408	Urrichem by Soliditech	8.91	TON	93.50	0.00	0.00	0.00	833.09 FALSE	FALSE	FALSE
Dugway Proving Ground	DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33150421	Bulk Chemical Transport (40,000 Lb Truckload)	8	EA	0.00	0.00	0.00	2,942.50	23,540.00 FALSE	FALSE	FALSE
Dugway Proving Ground	DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33150437	Maintenance of Solidification/Stabilization Unit	0.09	YR	0.00 1	3,753.11	0.00	0.00	1,237.78 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33150438	Solidification/Stabilization Equipment Cost	1.1	MO	0.00	0.00	0.00	8,158.34	8,974.17 FALSE	FALSE	FALSE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33150439	Operational Labor -In Situ Solidification/Stabilization	192	HR	0.00	766.94	0.00	0.00	147,252.76 FALSE	FALSE	FALSE
Dugway Proving Ground	I DPG	Dugway Proving Groun	na DPG	Pressurized Grouting	15	In Situ Solidification	33150440	Mobilize/DeMobilize of In Situ Solidification/Stabilization Equipment	1	EA	0.00	2,062.50	1,496.55	0.00	3,559.05 FALSE	FALSE	FALSE
Dugway Proving Ground		Dugway Froving Group Dugway Proving Group		Pressurized Grouting	15	In Situ Solidification	33170810	Operation of Pressure Washer, Including Water, Scan, Electricity, Lobor	1	LA	0,002.20	74 60	0.00	0.00	1 642 04 FALSE	FALSE	FALSE
Dugway Proving Ground		Dugway Proving Group		Pressurized Grouting	15	In Situ Solidification	33420101	Electrical Charge	324	KWH	0.00	0.00	0.00	0.00	49 90 FALSE	FALSE	TRUE
Dugway Proving Ground	d DPG	Dugway Proving Groun	nd DPG	Pressurized Grouting	15	In Situ Solidification	33420201	Diesel Fuel	3360	GAL	2.30	0.00	0.00	0.00	7,724.64 FALSE	FALSE	FALSE
and write and the second second fields		an ann Araban Araban - an that an Araban Station	(1995)		15 Total										215,019.08		
					Grand Total										1,985,415.55		